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DEMAND FOR ENERGY IN INDIA

1960–1975

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NATIONAL COUNCIL OF
APPLIED ECONOMIC RESEARCH
NEW DELHI

DEMAND FOR ENERGY IN INDIA

1960-1975

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PREFACE

Ever since its establishment, the National Council of Applied Economic Research has concerned itself with problems of energy and their bearing on the course of industrial and economic development in the country. Early in 1957, it undertook a comprehensive programme of research covering the entire field of energy development in India with a view to estimating the country's future requirements of coal, hydro-electricity, petroleum and, possibly, nuclear power, in the context of our expanding economy. A brief interim report on this study appeared in March 1958 under the title *Utilization of Primary Energy in India,* which dealt chiefly with the production, consumption and utilization of heat and power from primary sources, viz., coal, water, power and oil. A second publication in the series, *Domestic Fuels in India* (October 1959) was an attempt, in many ways a pioneer one in the country, at assessing the requirements of household energy in the future and investigating ways of replacing secondary energy by fuels of primary source. The present study, the third in the series, is a comprehensive, but necessarily rough analysis of the maximum plausible demand for different types of fuels that the Indian economy may require in order to maintain a certain pace of growth in the coming decade and a half. It presents estimates of demand for coal, hydro-electricity, petroleum and nuclear power for quinquennial periods beginning with 1960 and ending in 1975.

A study of this kind has to begin with certain simplifying assumptions. The main assumption here has been that the Indian economy will grow at a steady and regular pace, that can significantly increase the demand for energy throughout this period of growth. It is also assumed that there will be no sustained barriers, economic or otherwise, to such a growth. Given these assumptions, the question posed is: what will be the country's energy requirements in the coming years if national income is to grow at about 5 per cent every year and per capita income is approximately doubled between 1950 and 1957?[*] This report seeks to answer this question through a detailed, step-by-step analysis of the problem, beginning with a review of the current energy situation and its relation to economic structure, technological and other implications involved in the process of transforming a subsistence pattern of life into a modern industrial economy, and, on the basis of certain derived correlations, concluding with estimates of future demand by sources and type of energy.

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[*] *Second Five Year Plan*, Planning Commission, p. 11.

The subject is complex and the future is uncertain. This report is by no means the last word; but it should serve to direct attention to a vital problem. The actual requirements may vary from the estimates projected in these pages, but care has been taken to see that the methods adopted are explained in as precise a manner as possible, so as to allow for suitable corrections to be applied as and when necessary. Despite these limitations, it is hoped that the projections will provide a sound basis for planning the expansion of future energy supplies in the context of a general economic policy for the country.

A study of this type would be almost impossible without a large measure of cooperation from the several agencies and institutions, official as well as non-official, concerned with energy matters in this country, and my thanks are due to them for their valuable assistance. A number of individuals have contributed to the project through discussion, by reading the preliminary drafts, in whole or in part, offering expert advice and generally associating themselves with the project at various stages. The Council is indebted to persons in different departments, the Planning Commission, Ministries of Steel, Mines and Fuel, Commerce and Industry, Burmah-Shell etc. I would, however, like to thank in particular Dr. H. J. Bhabha, Chairman, Atomic Energy Commission; Prof. M. S. Thacker, Director-General, Council of Scientific and Industrial Research, Mr. M. Hayath, Chairman, Central Water & Power Commission and Dr. A. Lahiri, Central Fuel Research Institute, Dhanbad. The Council is also obliged to Prof. J. B. Condliffe, Council's Consultant, for his advice and interest in the project. None of these persons, however, are in any way accountable for the opinions expressed in the report for which the Director-General and staff take full responsibility.

The Council is also indebted to the management of Burmah-Shell, at whose initiative the project was first undertaken and who have materially assisted the Council in its execution. It need hardly be added that they are not necessarily in agreement with the findings of the report, nor do they accept any responsibility for it. The report was prepared by the staff of the Energy and Natural Resources Section of the National Council headed by Dr. J. Dubashi, under the guidance and direction of the Director-General and reflects the collective judgment of the National Council. It is hoped that the study will prove to be a useful contribution to knowledge in an important field of national economy.

NEW DELHI
January 1960

P. S. LOKANATHAN
Director-General

CONTENTS

Page

Preface by P. S. Lokanathan v

I. ENERGY CONSUMPTION AND ECONOMIC ACTIVITY 1

II. STATEMENT OF THE PROBLEM AND METHODOLOGY 11

III. OVERALL ESTIMATE OF ENERGY CONSUMPTION 19

IV. DEMAND FOR ELECTRICITY 34

V. ENERGY IN HOUSEHOLDS 50

VI. ENERGY IN TRANSPORTATION 62

VII. ENERGY IN INDUSTRY 80

VIII. ENERGY IN AGRICULTURE 91

IX. CONSUMPTION BY TYPE OF ENERGY 99

X. SUMMARY AND CONCLUSIONS 118

TABLES 127

NOTES AND REFERENCES 137

INDEX 159

LIST OF TABLES

		Page
2. 3.1	National Income of India, 1955-56—1975-76.	13
2. 4.1	National Income of India by Sectors, 1950-51—1975-76.	14
3. 1.1	Effective Energy Demand (constant elasticity), 1960-75.	19
3. 2.1	Effective Energy Demand (increasing elasticity), 1960-75.	20
3. 2.2	Effective and Gross Energy Demand, 1960-75.	20
3. 3.1	Effective and Gross Energy Demand, 1955 to 1975.	21
3. 3.2	Commercial and Non-commercial Energy Demand, 1956 to 1976.	21
3. 6.1	Summary of Estimates of Energy Demand, 1960-75	24
3. 8.1	Growth of Output in Industry, 1955-56—1975-76.	25
3. 8.2	Relation between Energy Consumption and GNP by sectors, 1955-75	26
3. 9.1	Energy Consumption in Industry and Transportation, 1955-75	26
3.10.1	Consumption of Gross Energy and Electricity by Expenditure Group in Households in Delhi City, 1958	27
3.10.2	Expenditure on Electricity and Fuels by Income Group in Households in England, 1948-49	28
3.10.3	Estimates of Energy Demand in Households, 1955-56—1975-76	29
3.10.4	Estimate of Energy Consumption in Industry, Transportation and Households, 1955-75	29
3.11.1	Energy Consumption in Services as a Percentage of Total Consumption	30
3.11.2	Estimate of Energy Consumption in Services, 1960-75	30
3.11.3	Estimate of Effective Energy Consumption in Services, 1960-75	31
3.12.1	Estimate of Total Net Energy Consumption, 1960-75	32
3.12.2	Estimate of Total Energy Consumption by Sectors and Type of Energy, 1955-75	32
4. 2.1	Estimate of Per Capita Consumption of Electricity (constant elasticity), 1955-75	36
4. 2.2	Estimate of Per Capita Consumption of Electricity (varying elasticities), 1955-75	37
4. 3.1	Estimate of Aggregate Demand for Electricity (doubling period basis), 1956-61—1971-76	37
4. 4.1	Industrial Production and Effective Electricity Consumption, 1950-56	38
4. 4.2	Estimate of Total Effective Consumption of Electricity, 1955-75	38
4. 4.3	Summary of Estimates of Consumption of Electricity, 1955-75	39
4. 5.1	Coefficient to Electrification in Industry, 1950-56	40

Page

4. 6.1 Estimate of Index of Industrial Electricity, 1955-75 40
4. 6.2 Estimate of Consumption of Electricity in Industry, 1955-75 41
4. 7.1 Estimate of Demand for Electricity in Households, 1955-75 41
4. 7.2 Estimate of Demand for Electricity in Urban Households, 1955-75 42
4. 7.3 Estimate of Demand for Electricity in Rural Households, 1955-75 42
4. 8.1 Correlation between Electricity Consumption in Households and Services, 1950-56 43
4. 8.2 Estimate of Consumption of Electricity in Services, 1955-75 43
4. 9.1 Estimate of Demand for Electricity for Irrigation, 1955-75 44
4.10.1 Estimate of Demand for Electricity in Traction, 1955-75 45
4.10.2 Estimate of Demand for Effective Electricity in Traction, 1955-75 45
4.11.1 Estimate of Demand for Electricity by Sectors, 1955-75 46
4.11.2 Conversion Coefficients for Electricity, 1955-75 47
4.11.3 Balance-sheet of Demand for Electricity, 1955-75 47
4.12.1 Balance-sheet of Demand for non-electrical Energy, 1955-75 48
5. 1.1 Source of Heat in Households, 1955 50
5. 2.1 Consumption of Kerosene in Urban and Rural Households, 1958 51
5. 2.2 Consumption of Kerosene for Lighting in Urban and Rural Households, 1958 52
5. 2.3 Consumption of Kerosene for Lighting and Heat in India, 1958 52
5. 2.4 Estimate of Demand for Kerosene for Lighting in Urban areas, 1955-75 53
5. 2.5 Estimate of Demand for Kerosene for Lighting in Non-electrified Rural areas, 1955-75 53
5. 2.6 Estimate of Demand for Kerosene for Lighting in Electrified Rural Areas, 1955-75 54
5. 2.7 Estimate of Demand for Kerosene for Lighting in Urban and Rural areas, 1955-75 54
5. 3.1 Estimate of Demand for Energy in urban Households, 1955-75 55
5. 3.2 Estimate of Demand for non-electric Heat in Urban Households, 1955-75 55
5. 3.3 Estimate of Demand for Kerosene for Domestic Heat, 1955-75 (basis A) 56
5. 3.4 Estimate of Demand for Kerosene for Domestic Heat, 1955-75 (basis B) 57
5. 3.5 Estimate of Demand for Kerosene for Domestic Heat, 1955-75 (basis C) 57
5. 3.6 Summary of Estimates of Demand for Kerosene for Domestic Heat, 1955-75 58
5. 3.7 Estimate of Demand for Kerosene for Heat and Lighting in Households, 1955-75 58
5. 4.1 Estimate of Demand for Household Energy for Lighting and Heat by type of Energy, 1955-75 59
6. 2.1 Consumption of Coal in Railways, 1955-56 63

Page

6. 2.2 Goods Traffic on Indian Railways, 1955-56 63
6. 2.3 Specific Consumption of Energy in Rail and Road Transportation 64
6. 3.1 Estimate of Goods Traffic by Rail, 1955-56—1975-76 65
6. 4.1 Estimate of Goods and Passenger Traffic by Rail, 1955-56—1975-76 66
6. 6.1 Estimate of Demand for Energy for Hauling Goods and Passenger Traffic by Rail, 1955-56—1975-76 67
6. 6.2 Demand for Coal, Electricity and Diesel Oil in Railways, 1955-56—1975-76 68
6. 7.1 Estimate of Production of Agricultural, Mineral and Industrial Commodities in India, 1955-56—1975-76 69
6. 7.2 Estimate of Long-distance Traffic by Railways, 1955-56—1975-76 70
6. 7.3 Estimate of Rail, Road and Miscellaneous Traffic, 1955-56—1975-76 71
6. 7.4 Estimated Growth of Rail and Road Traffic, 1955-56—1975-76 72
6. 8.1 Estimate of Trucks required for Feeder Traffic on Roads, 1950-51—1975-76 73
6. 8.2 Estimate of Trucks required for Local Traffic on Roads, 1960-61—1975-76 73
6. 8.3 Estimate of Trucks required for Long-distance Traffic on Road, 1960-61—1975-76 74
6. 8.4 Estimate of Trucks required for Long-distance Feeder and Local Traffic on Roads, 1955-56—1975-76 74
6. 8.5 Estimate of Petrol and Diesel Trucks, 1960-61—1975-76 75
6. 9.1 Estimate of Passenger Buses and Motor-cars, 1960-61—1975-76 75
6.10.1 Estimate of Demand for Petrol for Passenger and Goods Traffic on Roads, 1950-51—1975-76 76
6.10.2 Estimates of Demand for Diesel Oil for Passenger and Goods Traffic on Roads, 1950-51—1975-76 76
6.10.3 Estimates of Demand for Petroleum 1960-61—1975-76 78
6.10.4 Estimates of Demand for Petrol and Diesel Oil, 1960-61—1975-76 78
6.11.1 Estimates of Demand for Petroleum in Aviation and Shipping, 1960-61—1975-76 79
7. 1.1 Value of Industrial Output, 1950-51—1960-61 80
7. 1.2 Estimate of Growth of Output in Industry, 1960-61—1975-76 81
7. 2.1 Estimate of Output in Heavy Industries, 1955-56—1975-76 82
7. 3.1 Estimate of Demand for Energy in Industry, 1955-56—1975-76 82
7. 4.1 Coefficient of Electrification in Industry, 1950-56 83
7. 4.2 Estimate of Coefficient of Electrification in Industry, 1960-75 85
7. 5.1 Estimate of Demand for Electricity in Industry, 1960-75 85
7. 6.1 Estimate of Demand for Non-electrical Energy in Industry, 1960-75 86
7. 6.2 Petroleum Coefficient in Industry, 1955 86
7. 6.3 Price of Coal and Fuel oil in selected States, 1956 87

Page

7. 7.1 Estimate of Demand for Petroleum in Industry (constant coefficient), 1960-75 88
7. 7.2 Estimate of Demand for Petroleum in Industry (rising coefficient), 1960-75 89
7. 7.3 Estimate of Demand for Coal in Industry, 1960-75 90
8. 2.1 Livestock Census of India, 1956 92
8. 2.2 Animal and Mechanical Draft Power in the World, 1930-48 93
8. 2.3 Number of Tractors in selected Countries, 1930-48 93
8. 2.4 Agricultural Implements in India, 1945-56 94
8. 2.5 Progress of Mechanized Cultivation in India, 1945-55 94
8. 2.6 Estimate of Area under Mechanical Cultivation, 1955-56—1975-76 95
8. 2.7 Estimate of Oil Consumption by Tractors, 1960-61—1975-76 95
8. 3.1 Estimate of Oil Consumption by Oil Engines, 1956-76 96
8. 4.1 Estimate of Demand for Energy by Sectors, 1960-75 98
9. 1.1 Estimate of Demand for Effective Energy by type of Energy, 1950-75 99
9. 1.2 Pattern of Effective Consumption of Coal, Electricity and Petroleum, 1950-75 100
9. 2.1 Effective Consumption of Electricity, 1960-75 101
9. 2.2 Estimated Output of Diesel Stations, 1950-75 102
9. 2.3 Estimate of Demand for Oil by Diesel Stations, 1960-75 104
9. 2.4 Estimated Output of Electricity from Petroleum Fuels, 1960-75 105
9. 6.1 Estimated Output from Nuclear Stations, 1960-75 109
9. 7.1 Estimates of Output from Steam and Hydro Stations, 1960-75 111
9. 8.1 Pattern of Generation from Steam, Hydro, Petroleum and Nuclear Stations, 1960-75 111
9. 8.2 Pattern of Generation (mtce) from Steam, Hydro, Petroleum and Nuclear Stations, 1960-75 111
9. 9.1 Estimate of Gross Demand for Coal, 1960-75 112
9. 9.2 Estimate of Gross Demand for Petroleum, 1960-75 112
9. 9.3 Estimate of Gross Demand for Electricity by Source, 1960-75 113
9. 9.4 Estimate of Installed Capacities of Steam, Hydro Petroleum and Nuclear Power Stations, 1960-75 113
9.10.1 Pattern of Gross Demand for Energy by Source, 1950-75 115
9.11.1 Percentage Distribution of Gross Energy Consumption by Source, 1950-75 115

LIST OF TABLES

Page

I. Consumption of Primary and Secondary Energy in India by Sectors, 1950 129

II. Consumption of Primary and Secondary Energy in India by Sectors, 1955 131

III. Projected Demand for Primary Energy in India, 1960 133

IV. Projected Demand for Primary Energy in India, 1965 134

V. Projected Demand for Primary Energy in India, 1970 135

VI. Projected Demand for Primary Energy in India, 1975 136

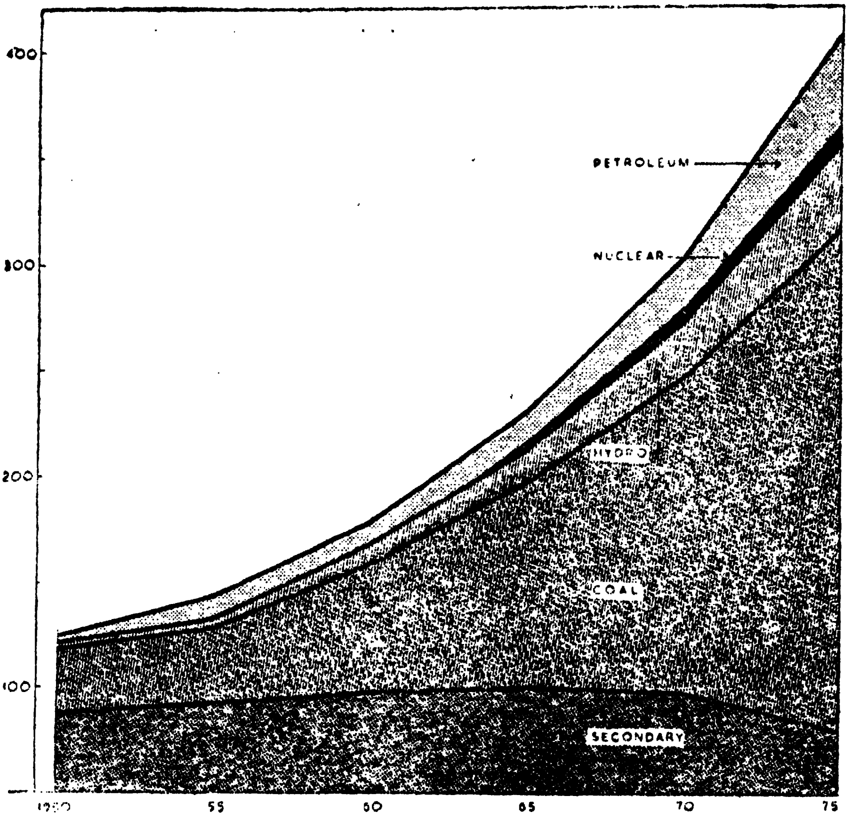
LIST OF CHARTS

DEMAND FOR ENERGY BY SOURCE, 1950-75

(*Frontispiece*)

1. Correlation between Total Net per capita Consumption of Energy and Gross per capita Product, average—1949-51 2
2. Correlation between per capita Consumption of Electricity and Gross per capita Product, average—1949-51 35
3. Demand for Energy in Households, 1955-75 60
4. Share of Fuels in Total Domestic Energy, 1955-75 61
5. Demand for Petrol and Diesel Oil Transportation 77
6. Relative Rates of Growth of Demand for Energy in Rail and Road Transportation, 1955-56 to 1975-76 77
7. Demand for Energy in Rail Transportation, 1955-56 to 1975-76 79
8. Coefficient of Electrification in selected Industries, 1950-56 84
9. Demand for Energy in Industry, 1955-75 90
10. Demand for Effective Energy in Industry, Transportation, Households and Services, 1955-75 97
11. Share of Coal, Electricity and Petroleum in Effective Energy Consumption, 1950-75 100
12. Output of Electricity by Source of Generation, 1955-75 110
13. Percentage Contribution of Secondary to Total Energy, 1950-75 114
14. Share of Coal, Hydro-Electricity, Petroleum and Nuclear Power in Gross Energy Consumption, 1950-75 114
15. Per capita Consumption of Primary and Total Energy, 1950-75 126

DEMAND FOR ENERGY BY SOURCE, 1950-1975



CHAPTER I

ENERGY CONSUMPTION AND ECONOMIC ACTIVITY

1.1 Despite its rather modest contribution to the gross product, energy plays a decisive, albeit indirect role, in economic development, since, to the extent that it is available, it stimulates or hinders economic growth. The shortage of energy undoubtedly constitutes one of the obstacles which most seriously limit the economic process, a low level of consumption being clear indication of a state of under-development. In addition, it should be noted that energy is of universal use, being not only a component of the productive process, but also an element fundamental to welfare. It is advisable therefore to draw a distinction at the outset between energy as a factor of production and energy as a consumer good.

Economic development basically implies an increase in the average productivity of labour force. Such an increase is directly influenced by the amount of energy which man is in a position to incorporate in the productive process. The productivity of various economic activities is a direct function of the amount of energy used and the form in which it is used. An increasing and rational use of energy is, therefore, a pre-requisite for the technical improvement of all kinds of economic activities: it is essential for raising productivity levels and for remedying the technical and economic backwardness of under-developed countries.

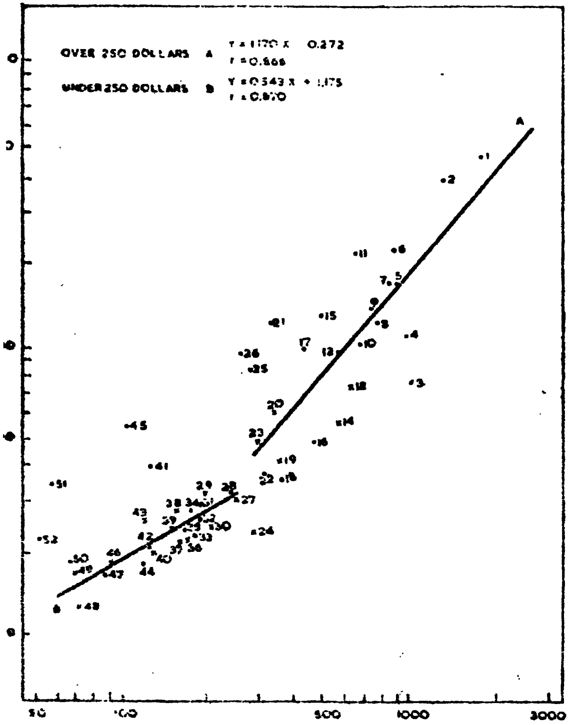
1.2 Fig. 1 is concerned with the relationship between per capita incomes and per capita energy consumption in about 50 countries for a recent period (averages for the years 1949-50-51).[1] Despite substantial deficiencies in the data concerning both national income and energy consumption, there is ample evidence of a rough but unmistakable positive correlation between per capita incomes and per capita energy consumption. Large differences in income are associated with large differeces in energy intake and it may be taken for granted that no country at this stage of history can enjoy a

---

[1] This and succeeding reference figures in the text indicate Notes and References on pp. 137-56.

FIGURE 1

ORRELATION BETWEEN TOTAL NET PER CAPITA CONSUMPTION OF ENERGY AND GROSS PER CAPITA PRODUCT, AVERAGE—1949-51 (LOGARITHMIC SCALE)



Order of Countries

1. United States
2. Canada
3. Switzerland
4. New Zealand
5. Sweden
6. United Kingdom
7. Australia
8. Denmark
9. Norway
10. France
11. Belgium & Luxemburg
12. Venzuela
13. Netherlands
14. Argentina
15. Germany (Fed. Rep.)
16. Israel
17. Ireland
18. Spain
19. Urguay
20. Cuba
21. Finland
22. Italy
23. Chile
24. Costa Rica
25. Austria
26. Union of South Africa
27. Panama
28. Yugoslavia
29. Mexico
30. Colombia
31. Brazil
32. Turkey
33. Greece
34. Portugal
35. Egypt
36. Guetamala
37. Honduras
38. Dominican Republic
39. El Salvador
40. Nicaragua
41. Japan
42. Ecuador
43. Peru
44. Ceylon
45. Southern Rhodesia
46. Paraguay
47. Thailand
48. Haiti
49. Bolivia
50. India
51. Northern Rhodesia
52. Belgian Congo

SOURCE: *Energy in Latin America*, United Nations, 1957.

Y = Total net per capita consumption of energy (kg of petroleum equivalent)
X = Gross per capita product (dollars at 1950 prices)
× = Latin American countries
. = Other countries

high per capita income without becoming an extensive consumer of energy.

Despite this marked relationship, there are substantial differences in per capita energy consumption among countries with similar per capita incomes. There are certain obvious reasons for these discrepancies including the extent of industrialization, the product mix of industry, the relative importance of energy-intensive processes in the industrial structure, climate, efficiency of utilization and differences in energy costs. Although the available data are not sufficiently reliable to justify an elaborate statistical analysis of the relative importance of these variables, certain observations are in order: transport, mining, energy production and a number of manufacturing activities are energy-intensive economic activities as compared with both agriculture and services, and consequently countries with a higher proportion of the former tend to have higher per capita consumption. About 65 per cent of the world's energy consumption is accounted for by manufacture and transportation, though not more than one-fifth of the gainfully employed are engaged in these activities.[2] It is interesting that the country having the highest proportion of Gross National Product (GNP) originating in agriculture, forestry and fishing (viz. Thailand 57 per cent in 1950) and the highest rate of employment in this activity (88 per cent) also ranks among the very lowest consumers of energy on a per capita basis (0.29 metric tons in 1949). It is also interesting to note that Japan which had a relatively low per capita income ($ 165 in 1952) was a relatively large consumer of energy (1.07 metric tons in 1952). On the other hand, there are certain countries like Ireland and Finland which are not extensively industrialized, but have relatively high rates of energy consumption (because of their relatively high per capita incomes). Canada, to cite another instance, is less highly industrialized than the United States and her per capita income is substantially lower. Yet Canada's energy consumption per head is nearly as high as that in the U.S., and in a few years may be higher. The main reason for this is, of course, the high proportion of the Canadian industrial complex that is made up of electro-processing industries, including aluminium, which ranks about at the top of the list of major energy consumers per ton of product.[3] Norway is another example of a country that, though not particularly highly industrialized, has a high per capita energy consumption because of the composition of her industrial activity.

1.3 In relating energy requirements to prospective rates of economic growth, it may be useful to consider the countries of the world in three categories. To the first group belong, what might be called, mature industrial economies including the U.S., most of Western Europe and, perhaps, some other areas. These are economies that have demonstrated a capacity for economic growth in terms both of increasing national income and of income per capita and have developed institutions and customs that generate continuous economic growth.[4] The position of industrial activities in these countries has tended to become relatively stable in the short-term and to follow persistent trends over the longer run. Energy requirements in these economies tend to increase at about the rate of GNP or more slowly ($\varepsilon = 1$ or < 1). In the United States, the BTU* input per dollar of GNP at 1939 prices declined from 300,000 in 1909 to 230,000 in 1952. Putnam's figures for the U.K. show a 50 per cent decline in 80 years and for Japan a 20 per cent decline in 15 years.[5]

A second group of countries is clearly in midstream of a process of rapid industrialization. A number of Latin American countries as well as certain areas in Eastern Europe belong in this category. These countries have either attained or are in a fair way towards attaining an institutionalization of the process of economic growth; they are 'over the hump' that separates the relatively stagnant under-developed areas from the technologically advanced, capital-intensive areas where increases in per capita income have become quasi-automatic. At the same time, they are differentiated from the economies in our first category by the fact that industry (manufacture, mining and transport) accounts for an increasing—in some cases a very rapidly increasing—per cent of total empolyment, mainly at the expense of agriculture. Energy consumption in these countries tends to increase more rapidly than GNP mainly because of the increasing relative importance of transportation and industrial sectors in these economies ($\varepsilon > 1$).

The third group of countries—and this includes India—comprises most of the so-called under-developed areas of the world where per capita incomes are not low but have not increased substantially over recent decades.[6] It is usually a mistake to consider these areas as economically stagnant since frequently expanding enclaves of technologically advanced economic activity are to be found. But over most of the area in question these exceptions remain enclaves that are not organically related to a growth process that can confidently be expected to produce for the economy as a whole a continuous increase in per capita incomes. At the same time, there is in most countries comprising these under-developed areas a strong determination on the part of governments to bring about economic development and a disposition on the part of economically advanced countries, for which there is little historical precedent, to assist in this development. Consequently, it would be a mistake to attempt to assess probable energy requirements for these countries by projecting past trends of energy consumption. In these countries, for reasons explained later, energy requirements tend to grow slower than GNP ($\varepsilon < 1$).

---

* BTU : British Thermal Unit.

1.4 After analyzing historical behaviour and international situation, it seems advisable to formulate a tentative hypothesis on the behaviour of consumption of total energy in relation to economic activity. In the initial stages of development, consumption of energy generally grows at a slower rate than GNP, and, therefore, unit consumption (i.e. consumption per unit GNP) declines with time. Later, at intermediate levels of development—when there are marked changes in the structure of production, mainly consisting in the greater expansion of industry and other activities where energy inputs are proportionately higher and in a more intense growth of residential consumption—supply requirements will increase at least as rapidly as GNP (elasticity close to unity), or even more ($\varepsilon > 1$). Finally, when a high degree of development is reached and the various production sectors acquire a more stable structure, unit consumption will again decline, this time owing to the possibility of improved efficiency in the use of energy and to a partial saturation of residential demand.

1.5 Referring again to Fig. 1, it will be seen that the slope of the trend curves for countries with per capita incomes of less than and over 250 dollars is 0.6 and 1.17 respectively. With an elasticity of 0.6 for countries with low income (including India), a 10 per cent rise in income tends to raise per capita consumption of energy by 6 per cent. The elasticity close to unity, characteristic of more developed countries, likewise means that for each 1 per cent increase in income a similar improvement can be expected in the demand for energy.

The relationship between the variation in the consumption of energy as a function of income fluctuations should necessarily coincide with the historical behaviour of both factors. Unfortunately national income figures are available for India only from 1948-49 onwards. If these figures are correlated with energy consumption figures for the corresponding years, an income elasticity very near 0.6 is obtained.[7]

1.6 The declining trend of unit consumption merits special attention. Since the GNP sectors consuming relatively high amounts of energy are increasing more rapidly than the other sectors, it is logical to expect that unit consumption should grow. The opposite trend might have been expected from a more efficient use of energy, but it is evident that in a country like India the degree of technical improvement is not enough to bring about such an effect. The reason for such a low income elasticity must, therefore, lie in the demand for energy as a consumer good, the slower growth of which in comparison with GNP has counteracted and annulled the greater relative increase of the demand for energy for productive purposes. This brings us to the two chief aspects of energy consumption: consumption as a factor in production in the fields of industry, agriculture and transportation; and consumption for the direct collective and individual needs of the people, that is, energy as a consumer good. In determining future prospects, it is necessary to take these two aspects of consumption into account, make an analysis of the various factors influencing them and further assume how these factors will operate in the future.

1.7 Energy consumption in industry (in any industry, not necessarily manufacturing) may be evaluated in relation to the production of individual products, and in relation to the number of working hours of workers. Energy used up per unit of production, that is, the specific consumption of energy, decreases, on the one hand, due to a reduction of the losses connected with a particular method of use; but, on the other hand, new methods of using energy are continuously being invented, which replace manual labour more and more every day and improve production processes, thus increasing specific consumption. The ratio of energy consumption to the number of working hours, the so-called 'power quota' of the labour always goes on increasing, and with it, the productivity of labour.[8] The national per capita product is a function of productivity in different sectors and the pattern of occupational structure.[*] Development alters the level as well as the structure of demands and supplies so that as economic activity expands there are changes induced in the composition of the GNP through changes in productivity and occupational pattern. A doubling of national income does not mean that all products and services in the community flow in it twice the initial rate. Development involves a transfer of part of the working force from agriculture to secondary and tertiary activities, but this, in turn pre-supposes an increase in productivity in agriculture itself along with

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[*] The three variables, viz. actual production, P, the number of hours worked, L, and the energy consumed, E, are related to one another through another variable, production per man-hour, or productivity of labour. The relation can be expressed thus:

(*Contd. on p. 7.*)

productivity increases in other sectors to absorb the surplus working force. These changes are not easy to predict, but without a quantitative idea of their behaviour in the future, no valid estimates of energy demand can be made with a reasonable degree of accuracy.

The experience of other countries in the course of their economic development discloses a general tendency for primary employment to decline relatively to employment in industry and services.[9] Between 1870 and 1930 the proportion of the active population employed in agriculture declined from 54 per cent to 23 per cent in the U.S., from 42 per cent to 25 per cent in France and from 80 to 48 per cent in Japan. In Germany, this proportion declined from 39 per cent in 1880 to 22 per cent in 1930, and in the U.K., from 15 per cent in 1870 to 7 per cent in 1920. Recent data regarding Latin American countries also show a certain shift of labour from agriculture to industry during the post-war period: between 1945 and 1950, the agricultural labour force in that region declined from 60 to about 58 per cent while the per capita GNP showed an average rate of increase of 4 per cent per annum.

In India, there has not been a marked change in the occupational pattern over the last three or four decades in spite of considerable increases in industrial production.[10] Broadly speaking, agriculture and allied pursuits continue to absorb about 70 per cent of the working force; mining, factories and small enterprises including construction, take up some 10.6 per cent;

$$p = \frac{m}{n}$$

Where n = specific energy consumption = $\frac{E}{P}$

m = power quota of labour = $\frac{E}{L}$

p = productivity of labour = $\frac{P}{L}$

This means that labour productivity grows faster with power equipment, and with a decrease in specific consumption of energy. The latter is inversely proportional to the efficiency of the productive process, so that the above expression can also be expressed as

$$p = k.m.n'$$

where n' is the efficiency of production and k is a constant. This may be stated as a basic relationship between energy consumption and economic growth. At a given level of technological efficiency, $p \propto m$.

about 7 per cent is engaged in transport, communications and trade; and the services absorb over 10 per cent. This means that the secondary and tertiary sectors have not grown rapidly enough to make an impact on the primary sector; nor has the primary sector itself thrown up surpluses which would create conditions favourable for expansion elsewhere. The net result has been a quasi-stagnant economy.[11]

1.8 The energy consumption function can be written as $E = E_p + E_c$ where E is total energy consumed; E_p = energy consumed as a factor in production; and E_c = energy consumed as a consumer good mainly in the domestic and services sectors. In India, roughly 70 per cent of the total energy consumption is in these sectors, the rest being mainly in industry and transportation.[12] In more developed economies, the percentage of consumption in the domestic sector is generally lower than 50 per cent, the percentage in the U.S. being as low as 25 per cent in domestic and commercial services combined.[13] The ratio of the two coefficients is an important indicator of the level of economic growth, since a relatively higher percentage of utilization of energy as a producer good obviously results in a higher rate of growth.

Data regarding income elasticities of domestic energy consumption is extremely meagre, but it is generally agreed that they are very low and probably lie within 0.18 and 0.20. In the three cities, viz. New Delhi, Bombay and Calcutta, in which NCAER recently carried out the sample surveys,[14] expenditure elasticity for total domestic energy was found to be 0.225. This was also roughly the figure in England at the turn of the century.[15] Because of this relatively low elasticity of domestic energy demand, 10 per cent rise in per capita income leads to an increase of 1.8 per cent in domestic energy consumption and 15.8 per cent increase in consumption in other sectors.* Since the domestic energy component of under-developed countries is generally a large one, the aggregate elasticity of energy demand for countries like India is lower than unity, in fact as low as 0.6. As the standard of living rises, the low domestic elasticity also rises (particularly with

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* The energy consumption function, $E = E_p + E_c$ can be written as

$$\Sigma\varepsilon = \varepsilon_p \frac{e_p}{\rho} + \varepsilon_c \frac{e_c}{\rho}$$

where e and ε are per capita energy consumption and income elasticities of energy demand respectively; $\Sigma\varepsilon$ is aggregate income elasticity and ρ is per capita income. Since $E_c = 0.7E$, $\Sigma\varepsilon = 0.6$, and $\varepsilon_c = 0.18$, ε_p works out at 1.58.

respect to such energies as electricity which, at present, account for less than 1 per cent of the total domestic consumption) with the result that beyond a certain per capita income (about 250 dollars) the energy demand increases as fast as, if not faster than, the national income. The elasticity for energy consumed as a factor in production (which works out to 1.58 in India) is worth examining. For the years 1948-49 to 1955-56, the corresponding elasticity in India was found to be 1.4. This is, however, too short a span to be really more than just minimally useful; moreover, there is a lag between the application of energy and the generation of income, particularly in a sector like agriculture, so that an allowance has to be made for the time lag. Because of this, the period under examination is still further reduced and the results are much less reliable.

There is, however, another method by which the validity of $\varepsilon_p = 1.58$ can be confirmed. In almost all the poorer countries, secondary energy (that is, non-primary or non-commercial energy) is mainly, and sometimes, as in the case of India, wholly used in domestic consumption, the use of primary energy being chiefly restricted, for obvious reasons, to productive sectors. In India, only about 10 per cent of the total primary energy is used in households. The use of primary energy in countries at India's level of economic development can, therefore, be considered a good indicator of ε_p. It was found that the income elasticity of primary energy demand in such countries was of the order 1.415 to 1.76, the average being a little less than 1.6.[16] Our figure of $\varepsilon_p=1.58$ can, therefore, be taken as fairly accurate in the context of present Indian conditions of economic growth.

1.9 These elasticities are broad indicators of the rate of change of energy consumption in a particular sector with respect to the general rate of change in the overall economy. But there may arise situations in which the historical behaviour on which they are based may not hold good in a particular context. For instance, a radical social and political philosophy may impose upon the consuming sector of the economy such restrictions as may lead to a lowering of elasticity of energy in domestic consumption (ε_c) far below its present value in order to direct the resources (energy included) to the productive sectors to the maximum extent possible. In such a case, the growth pattern will take a direction without precedent in history and will have to be assessed in its own particular context. In a planned economy of India's type where radical social and political philosophies are assumed to operate within a freely chosen democratic milieu, the consuming sector is expected to grow in the general direction of overall growth, although perhaps not as rapidly as in relatively less restricted 'free' enterprise economies. This assumption is implicit throughout this study.[17]

The relationship underlying economic growth and energy consumption is now fairly clear as also the nature of inter-sectoral relationships through which the growth process is operated. Taking per capita GNP[18] as our indicator of growth it has ben possible to derive basic relationships between the various economic sectors on one hand and the energy consumption therein on the other. We have to extend this analysis to individual types of energy on the strength of existing data and on certain other considerations based on historical behaviour of these types. This will be attempted in the chapters that follow.

CHAPTER II

STATEMENT OF THE PROBLEM AND METHODOLOGY

2.1 In order to project energy consumption requirements a knowledge of the following factors is essential:

(a) What, in the past, have been the outstanding characteristics of energy consumption, its relation to economic activity (energy/product), to the population (energy/per capita) and to the international picture?

(b) What has been its composition, and how has it varied?

(c) What is the anticipated rate of increase of GNP and what variations in its structure are envisaged?

(d) What is the increase expected in population and how is the rural-urban ratio likely to change?

Sometimes, in an analysis of this type, a simplified solution of the problem is often attempted through *independent* projections of past consumption trends for each type of energy over a given period. This, however, involves certain obvious and appreciable risks, and projections made on this basis are apt to lead to a substantial over- or under-estimation of further needs. The results obtained from the projection of historical trends will be satisfactory only if future developments conform to these trends, but they will certainly be erroneous if there is any variation in the rate of development and the consequent change in the economic structure. In India, both the rate and the structure will differ sharply in future so that a mere extrapolation of historical trends in consumption is certain to lead to entirely unreliable estimates. This approach, therefore, has been discarded in this study in preference to what may be called economic correlation approach in which future estimates are made by relating energy requirements, as closely as possible and in as many individual sectors as practicable, to economic development.

2.2 Starting with available statistics, the basic method employed has been to make an overall projection of total energy consumption and total electricity production, relating these to the hypothesis of economic development. The overall figure thus obtained serves as a useful frame of reference for dimensional analysis and as a guide for further sectoral breakdowns which can then be aggregated to give a more accurate estimate of total demand. Projections of energy demand by means of a selective analysis of the various economic sectors is a more accurate way of ascertaining the distribution of total energy consumption by types of fuel and of examining closely the possibilities of replacing one type of fuel by another. In the more developed countries, there is no great difference between the method by sectors and the overall method, but in a country like India, the change in economic structure (specially the progressively greater incidence of manufacturing activity) is a major factor to be taken into account and one which may substantially alter the consumption pattern and thereby to a certain extent, the total demand. The sectoral analysis has been carried further into certain specific industries within that sector, viz. iron and steel, cement etc. in the industrial sector and road and rail transport in the transportation sector. Information with regard to the development of these industries over the next two decades is now available (albeit in a rather sketchy and tentative form), and by applying suitable coefficients, individual estimates of demand likely to arise within each industry have been attempted.

Having made overall projections, the next point to be examined was the breakdown of the total by types of energy. Since electricity as a source of mechanical power is a very special and characteristic form of energy, estimates of electricity demand were made separately for different sectors, and then subtracted from the total energy demand to obtain requirements of coal and petroleum products. It may perhaps be mentioned that while electricity satisfies a very specific kind of demand for a particular form of power and heat, neither coal nor oil (except in special cases) meets any singular energy demand. Actually, although it can be said that there exists a demand for electricity in the sense that electricity as a form of energy is well-nigh irreplaceable in certain conditions of energy use, the demand for coal and oil is only an indirect one and is essentially a demand for industrial and domestic heat, and certain modes of transport. By isolating such exclusive sources of energy as motor spirit for automobiles, kerosene for lighting and coke for iron smelting etc., the aggregate demand for coal and oil has been broken down further into its coal and oil constituents on certain broad assumptions as regards the future possibilities of their substitution. The demand for electricity is also broken down into thermal, hydro and nuclear sources and an estimate of installed capacities necessary to meet this demand is made.

2.3 Energy consumption, it may be stated, is not an end in itself; inasmuch as it is a necessary overhead of economic growth, its growth conditions and is, in turn, conditioned by the latter. The ultimate aim is economic and social development of the nation on as large a front as possible, its pattern and magnitude being determined by factors which can be said to be, within certain limits, more or less, independent of energy considerations. The energy function is thus a derived function of economic growth and, for the purposes of this study, the latter can be treated as an independent variable.

In this study, the future course of the economy has been assumed to follow the lines of development postulated in the model given in the Second Five Year Plan with a slight modification towards the end of the period when the per capita income by 1975-76 is assumed to be Rs. 564 in lieu of Rs. 546 given in the Plan frame. This slight upgrading of national income and investing targets in the Fifth Plan will almost exactly double the per capita income in 20 years, from Rs. 281 in 1955-56 to Rs. 564 in 1975-76, and increase the national income from Rs. 108,000 million in 1955-56 to about Rs. 282,000 million at the end of the twenty-year period. The following table gives the synoptic view of the growth in income and population in the model under consideration:[19]

TABLE 2.3.1

NATIONAL INCOME OF INDIA, 1955-56—1975-76
(At 1952-53 prices)

	First Plan 1951-56	*Second Plan* 1956-61	*Third Plan* 1961-66	*Fourth Plan* 1966-71	*Fifth Plan* 1971-76
National income at the end of the period (Rs. million)	108,000	134,800	172,600	216,800	282,000
Population at the end of the period (Million)	384	408	434	465	500
Per capita income at the end of the period (Rs.)	281	331	396	466	564

2.4 It is now necessary to obtain sectoral breakdowns and to examine the variations in economic structure in the course of this development. On the basis of likely shifts in occupational distribution and changes in productivity (as discussed earlier) a broad sub-division of national income into constituent sectors has been made. The chief assumption has been that the agricultural labour force would come down to about 62 per cent of the total by 1975-76 and the rate of change of productivities in the various sectors would bear roughly the same relation to investment therein as it has been assumed to have done during the first two plans. The situation as it is likely to develop over the next three plans until 1975-76 is summarized below:

TABLE 2.4.1

NATIONAL INCOME OF INDIA BY SECTORS, 1950-51—1975-76

(million rupees)

Year	*Total national product*	*Agricultural & allied pursuits*	*Mining & manufacture*	*Trade, transport & communications*	*Services*	*Per capita income*
1950-51	91,000	44,500	15,900	16,500	14,200	253
1955-56	108,000	52,300	19,950	18,750	17,000	281
1960-61	134,800	61,700	29,100	23,000	21,000	331
1965-66	172,600	74,000	42,500	29,000	27,100	396
1970-71	216,800	88,000	59,000	35,400	34,400	466
1975-76	282,000	106,000	85,000	46,000	45,000	564

It will be seen that a doubling of per capita output involves more tha quadrupling of the industrial output and more than doubling of the service sector, while both the agricultural and transport sectors expand less tha the total national product. Consumption of energy in agriculture and services is extremely small not only in India but also in more developed countrie in relation to the consumption in other sectors.[20] The main energy-consuming sectors are mining and manufacture, and transport, and the fact tha their aggregate output will increase fourfold by 1975-76 is a major factor to be reckoned with in projecting energy demand.

In addition to these sectors which contribute to the national income and can, therefore, be called 'productive' sectors, there is another sector, viz. the domestic sector wherein energy is simply consumed and does not have a 'productive' role. In India, almost two-thirds of the total energy consumption is in households,[20] although the proportion is bound to decrease progressively with the relative rise in consumption in productive sectors. Whatever the actual proportion of these constituents, it is clear that the energy picture is dominated by these three sectors, the contribution of the rest being only marginal and relatively insubstantial.

2.5 Having established the outlines of the pattern of future economic growth, it is necessary to draw up the energy balance-sheet corresponding to the consuming sectors. Here, the concept of total energy, hitherto only an abstraction adopted for practical purposes, has to be more carefully defined. Energy comes from different sources, is transformed and consumed in different forms and is used for widely varying techno-economic purposes or aims, which present different basic characteristics. Yet it should be recalled that the diversity of sources of energy is of economic value since a country does not have to depend on a single source and may make better use of each. Whatever the forms of energy available, save for special cases which will be mentioned in due couse, they can all be used for the same economic purpose, that is to say, they are interchangeable. Therefore, whether the sources of energy are heterogeneous or not, the addition is not only possible but necessary in order to interpret developments within the energy sector and the relationships between the sector and general economic activity.

This relationship, it may be stated, is a dynamic one. Owing to constant technological innovations, the manner in which a particular form of energy is absorbed into the economy may change not only from one level of economy to another, but also within a given economic pattern from one sector to another. Even the so-called exclusive forms of energy are not really exclusive: even motor spirit in automobiles can be substituted by coal gas, though the efficiency may have to be reduced in the process. The ultimate deciding factor is the cost of such a substitution to the society and the capacity of the society to bear it.

Because the process of absorption of energy by the economy is essentially a technical one, it is desirable to distinguish between the different stages of this absorption process. In this study, the balance-sheet has been drawn up in terms of (a) *effective consumption,* that is consumption at the place where it is actually consumed; (b) *net consumption,* that is, effective consumption plus consumption required to process and transport the energy to the place of actual consumption; and (c) *gross consumption* including losses. In addition to these, there is a fourth stage, viz. *useful consumption,* that is, energy usefully consumed after allowing for efficiency of utilization. It is, however, extremely difficult to get reliable data regarding efficiency of use in various processes, particularly so in India where almost two-thirds of the total energy is in the form of vegetable fuels used in crude apparatus varying in design and efficiency and from one place to another. The concept of *useful consumption,* therefore, has not been adopted for projection purposes in this study although reference has been made to it in individual cases where it is obligatory to take this into account for realistic demand estimates. (vide Tables I and II, pp. 127-136)

2.6 Radical changes in the efficiency of use of energy can conceivably change the entire energy picture. In relating energy requirements to economic growth, it is, however, necessary to distinguish between technical efficiency of energy use and the non-technical efficiency in the economic processes of production and distribution. In under-developed countries, the former may register progressive increase with time if only because old plants are being gradually replaced by new, more efficient ones, but it is doubtful whether, in the initial years of industrial administration, there would be much scope for substantial efficiencies in non-technical fields. Because of this, the amount of energy per unit of income may not show much decline during the initial period of large-scale industrial expansion. Later, however, the position may be different and the rise in productivity may be relatively much more rapid than in countries with a longer and better established tradition of industrial economy.

Studies have revealed that a substantial part of the additional energy requirements during the past decades in all parts of the world had been met by increased efficiencies due to technological improvements. In the United States, average efficiency has nearly tripled in fifty years, rising from about 11 per cent in 1900 to about 30 in 1950.[21] In Great Britain, where per capita input appears to have remained stationary or has declined since 1883, per capita output has increased by nearly 300 per cent. Between 1920 and 1937, it is stated that the U.K. made savings by fuel economy to the extent of 50 million tons of coal per annum; Switzerland had increased its efficiency of utilization by 25 per cent and France is producing a saving of 1 to 2 per cent per year in its energy input. Taking one or two specific industries for which details are available in Great Britain, while total fuel requirements of the steel industry have increased by some 14 per cent between 1949 and 1955, steel production has gone up by 33 per cent.[22] The fuel required to produce a ton of *finished steel* has been reduced from some 65 cwts in 1920 to 34 cwts in 1955. In the steel industry, nearly three-quarters of the fuel consumed is in the form of coke for the production of pig iron in the blast furnaces. Here the coke plays a duel role, acting not only as a fuel but also, in combination with oxygen from the air, providing the carbon monoxide gas which reduces the iron ore to iron by chemical reaction. The coal equivalent required to produce one ton of iron has been successively reduced from 44½ cwts in 1920 to 36½ cwts in 1945 and 31 cwts in 1955.[23]

In India, there is tremendous scope for improvements in fuel utilization techniques. In the railways, the efficiency is of the order of 4 per cent,[24] so that a 10 per cent increase in efficiency would result in a saving of more than one million tons of coal a year. With dieselization, the saving would be still more: in Mexico, for instance, the railways carried 15 per cent more traffic in 1950 than in 1945 with 5 per cent less fuel consumption.[25] The replacement of vegetable fuels in households by commercial fuels like soft coke would result in a net saving of 1.4 cwts of coal equivalent of energy per person per year. A survey conducted by NCAER revealed that the *gross* domestic heat required per household in Bombay was much less than that consumed by a household in rural areas owing to the fact that kerosene, a popular cooking fuel in Bombay, burns with an efficiency almost three times that of wood and more than four times that of dung.[26] A large-scale substitution of wood and dung in households by coke or gas will certainly affect the overall gross energy requirements, to a much greater extent than the increase in efficiencies in industrial and transport sectors.

These increases, it need not be mentioned, are not automatic: they entail considerable expenditure in capital equipment and maintenance. In India, where a good proportion of energy needs are met without any monetary capital investment,[27] the saving in fuel through substitution will be an expensive process and one that may come about as a result of deliberate policy rather than as a projection of past trends. Moreover, it has no tangible relation to economic growth and higher standards of living, for a commercial fuel is not necessarily superior to the non-commercial variety, merely because it burns more efficiently. The process of substitution would, however, appear to be an inexorable historical process,[28] and there is no doubt that it will manifest itself in India also, although the exact rate of replacement and its effect on the energy pattern will remain a matter of speculation and intelligent guess, rather than of rational, scientific estimation.

2.7 Another important factor to be taken into account is the pronounced shift towards energy-intensive industries in the manufacturing sector that will come as a result of the broadening of the heavy industrial base in the next plans. For this reason, the industrial energy balance-sheet has been divided into four sub-sectors, viz. (a) metal, (b) non-metal, (c) textiles, and (d) rest. The metal and non-metal (mineral) processing industries are heavy consumers of energy or, rather, of industrial heat and account for almost 50 per cent of the net coal consumption. Generally, processes involving chemical reaction are bigger consumers of energy—mostly in the form of heat—than processes involving physical changes. More energy is required to produce one ton of iron or ingot steel than in rolling, planning, punching or fabricating the same weight of the metal for different purposes. The *primary* iron and steel and allied industries are, therefore, the pace-setters of energy growth, for an economy can absorb steel and other metal products without any appreciable shift in the energy balance if only a small amount of the metal is produced within the country. India's production of steel is expected to increase almost twice as fast as[29] the rest of the industrial production and this will bring about a substantial change not only in the overall energy pattern but also in the pattern within the industrial sector itself.

2.8 Having established the two balance sheets—national product and energy—and dwelt upon some of the more salient factors affecting the relationship of one with the other, it is now possible to proceed to actual estimates of energy requirements on the basis of these postulates. It will be realized that the multiplicity of known and unknown factors affecting the inter-relationship and the fact that the future economic pattern is only broadly visible from this distance make it almost impossible to be very precise and firm about the final estimates. This study is more in the nature of an exercise in dimensional hypothesis or, at best, an evaluation of the various alternatives that might justifiably and, within the limits set by the problem itself, serve as solutions to the problem.

CHAPTER III

OVERALL ESTIMATE OF ENERGY CONSUMPTION

3.1 Between 1950 and 1956, the unit total effective energy consumption per million rupees of national output has declined from 1.335 tons to 1.231 tons of coal equivalent (tce),* while primary energy consumption during the same period has gone up from 0.340 to 0.369 tce. This gives an elasticity for total energy of 0.605, that is, for a 10 per cent rise in national output, there is a 6 per cent rise in energy consumption. Using this correlation, the energy estimates would work out as under:

TABLE 3.1.1

EFFECTIVE ENERGY DEMAND (CONSTANT ELASTICITY), 1960-75

(mtce)

Year	*Total effective energy*
1960	151
1965	176
1970	204
1975	241

3.2 For reasons referred to earlier, 0.6 is certainly the lower limit of elasticities for India under the present conditions, for with the increasing pace of industrial activity, the industrial constituent of the energy pattern is likely to increase much more rapidly than the domestic constituent. It has been pointed out earlier that for countries above a per capita income of about 250 dollars per year, the elasticity is of the order of 1.2. It is, therefore, reasonable to assume that in India the operative elasticity will approach at least unity by 1975 (when the per capita income is Rs. 564). Assuming elasticities of 0.7, 0.8, 0.9 and 1.0 during the Second, Third, Fourth and Fifth Five Year Plans, the energy estimates would be as shown in Table 3.2.1.

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* For coefficient of energy conversion adopted in this study see p. 139.

TABLE 3.2.1

EFFECTIVE ENERGY DEMAND (INCREASING ELASTICITY), 1960-75

(mtce)

Year	Total effective energy
1960	154
1965	188
1970	231
1975	300

These are effective energy figures, that is, they do not take into account the energy required for extraction, processing and transport to the point of consumption. The gross demand will naturally depend upon the size of the primary energy constituent of the total energy. Assuming that the ratio of primary to total will increase from the current 30 per cent to, say, 75 per cent, as a first approximation, and assuming that roughly 20 per cent of energy is required to extract and transport it, the figures of gross consumption (including losses) would be as shown below:

TABLE 3.2.2

EFFECTIVE AND GROSS ENERGY DEMAND, 1960-75

(mtce)

Year	Effective energy	Gross energy
1960	154	167
1965	188	207
1970	231	260
1975	300	345

3.3 Perhaps a slightly higher figure would be obtained by assuming that the input of energy per unit national output would remain constant over the next fifteen years. This is tantamount to assuming elasticity of unity throughout the current and next three plans. In 1955, the net national output was Rs. 108,000 million and effective energy consumption 131.13 mtce, giving an unit input of 1.215 tons per million rupees. The estimates for the next few decades would be:

TABLE 3.3.1

EFFECTIVE AND GROSS ENERGY DEMAND, 1955-75

(mtce)

Year	*Effective energy*	*Gross energy*
1955	131	139
1960	164	177
1965	210	231
1970	264	296
1975	343	394

This is roughly the basis on which the Natural Resources Division of the Planning Commission made an approximate assessment of energy needs over the next few years.[30] The N.R. Division has not differentiated between effective and gross consumption.and has assumed equal elasticities for both with regard to national output. This is not strictly true as there is virtually no energy required to extract, process and transport non-commercial energy almost all of which is collected and consumed locally. Their figures are as follows:

TABLE 3.3.2

COMMERCIAL AND NON-COMMERCIAL ENERGY DEMAND, 1956-76

(mtce)

Year	1956	1961	1966	1971	1976
Total energy consumed	139.8	177	222	280	352
Less non-commercial energy	100.0	100	100	100	100
Net commercial energy	39.8	77	122	180	252

These figures agree fairly closely with ours as the method adopted is almost identical although it gives lower figures towards the end of the period. The Division has ignored the increase in efficiency in the use of commercial fuels as 'these will be offset by the increasing change-over from non-commercial to commercial fuels'. Actually, as pointed out in 2.6, the changeover is likely to lead to higher efficiencies, not lower. The figures, therefore, can be said to be over-estimates rather than under-estimates for it is inconceivable, as the Division has assumed, that the quantum of secondary energy would continue to remain at the same level of 100 million tons over the next few decades.

3.4 Perhaps the grossest over-estimate made in this connection is by the Committee on Requirements and Utilization of Fuel[31] which in its Preliminary Report (*July 1957*) *assessed the requirements of coal alone by 1975 as 300 million tons,* and total energy at 425 mtce. This is almost a hundred tons more than the estimate for 1975 in Table 3.1.1 and it would be interesting to know why this is so. The Committee states that

> "In assessing the future energy requirements we have analysed the forecasts on several and different bases, the results of which agree fairly closely. The target for the Second Five-Year Plan sets an annual increase of 5 per cent for the net output and an approximate doubling of the industrial production, which amounts to 15 per cent annually compound. The industrial production has been rising at the rate of 7.5 per cent during the First Plan and will be doubled during the Second Plan period. Since the main load will be on commercial energy for increase in output, an increase of ten per cent per annum (compound) may be considered as reasonable."

It is a pity that these assumptions are at variance with those enunciated in the Plan frame. During the Second Plan, the net output of mining and factory establishments is to go up from Rs. 935 million to Rs. 1530 million—an increase of *less than* 10.5 per cent annually compounded. During the First Plan, the index of industrial production rose from 100 to 133, a rate of increase of *less than* 6 per cent compounded annually, that is, about 20 per cent less than the figure assumed in the Committee's report. It appears, therefore, that the Committee is far more optimistic about the nation's economy than the planners themselves not only with regard to its performance in the past but presumably also in the future. The Committee, however, goes on to say that

> "On the basis of 10 per cent compound increase over total commercial increase in 1955, the projected requirement for 1975 is approximately 296 million tons of coal equivalent."

If we add to this 55 million tons of domestic commercial energy which, according to the Committee, will be roughly the size of replacement in that year, the total commercial energy requirements will be 351 mtce. Total energy, both commercial and non-commercial, will be 396 million tons. This last figure, it will be seen, compares with 394 million tons of Table 3.3.1, although in deriving the latter it was stated that it was probably an over-estimate. The Committee assumes that a 7.5 per cent rise in industrial production will correspond to a 10 per cent rise in commercial energy consumption, an assumption whose validity has yet to be tested. It is more likely that the elasticity of energy will be less than unity in this case, as the other consuming sectors like transport etc. will not expand at the same rate as industry. In any case, the figure of 396 million would appear to be more acceptable than 425, although it may be slightly on the higher side.

3.5 It would be interesting, in this connection, to examine China's performance in these matters.[32] During their First Five Year Plan (1953-57), industrial output is reported to have increased from 27,000 million yuan to 53,560 million yuan, an increase of 98.3 per cent corresponding to an average annual increase of 14.7 per cent. During this period, the output of coal which supplies almost the whole of China's energy needs, reportedly increased from 63 million tons to 113 million tons, an increase of about 80 per cent, that is less than the increase in industrial production. The increase in electrical capacity was 120 per cent. It may perhaps be mentioned here that the complement of heavy energy-intensive industries in their Plan is far bigger than ours: of the total investment, 88.8 per cent went into industries 'manufacturing means of production', and only 11.2 per cent into consumer goods industries.[33] It is because of this very low complement of consumer goods that the elasticity of electricity to industrial index is as low as 1.2. In India, in common with most other countries with more balanced economies, the elasticity is 1.75.[34] Although the Chinese experience may not be strictly comparable with ours, it is instructive to note that in China, *despite their concentration on heavy industries*, the rate of expansion of coal is about 20 per cent *behind* the general rate of industrial growth. In India, if anything, it should be lower than, not 33 per cent *ahead* of industrial index as assumed by the Committee.

3.6 The estimates by different approaches have been summarized in Table 3.6.1, from which it will be clear that the first and the last approach yield results that are somewhat extreme and have to be discarded in favour of the remaining three:

TABLE 3.6.1

SUMMARY OF ESTIMATES OF ENERGY DEMAND, 1960-75

Approach	1960	1965	1970	1975
Constant elasticity[a] (0.6)	151	176	204	241
Increasing elasticities[b]	167	207	260	345
Constant elasticity[c] (1.0)	177	231	296	394
Constant elasticity[d] (1.0)	177	222	280	352
Elasticity of 1.33 with index of industrial production[e]	177	232.5	320	425

[a] Net consumption.

[b] Gross consumption; elasticities of 0.7, 0.8, 0.9 and 1.0 in the Second, Third, Fourth and Fifth Plans respectively.

[c] Gross consumption.

[d] Gross consumption; non-commercial energy assumed constant throughout the years 1961, 1966, 1971 and 1976.

[e] Total energy; index of production increasing at 7.5 per cent compounded annually from 1955.

3.7 From these aggregate elasticities, it is necessary to go further and calculate individual sectoral elasticities. We shall consider only those sectors which have an organic relationship with energy, that is, sectors in which the generation of income is dependent almost entirely on consumption of energy. The two such sectors are industry and transport, the volume of production in either being organically related to energy consumption. From the extraction of ores to the manufacture of goods, energy, whether in crude animal form (including human energy) as in most under-developed countries or in the more sophisticated forms of refined and controlled energy, is a necessary element in all processes although its incidence may vary according to the type of processes adopted and the level of productivity aimed at. The function of the energy in industrial processes may be chemical, as in smelting of ores, or purely physical, as in fabrication and rolling. In transport, it is patently physical, from the carrying of stones for building to launching satellites in the heavens. Neither in agriculture nor in services is the function of energy such a direct and absolute one. Although energy does play a part in agricultural productivity, albeit indirectly, through the use of energy-consuming artificial manures, irrigation, etc., there are so many factors involved in raising agricultural productivity that it is doubtful whether energy can be singled out as the only really significant one. It is no wonder, therefore, that the direct consumption of energy in agriculture, even in countries that have attained a high level of productivity, remains a fraction of the total energy consumption. In services, the role of energy is both insignificant and intangible. Here too, for obvious reasons, the consumption of energy is generally insubstantial in comparison with other sectors.

3.8 In industry, the patterns of consumption vary as between heavy, producer goods industries, and consumer goods like textiles. It is, therefore, necessary to differentiate between the two right from the start so that the projections can be made on a firmer and more realistic basis. From Table 2.4.1, it will be seen that the mining and manufacturing sector (which includes factory enterprises as well as small enterprises and construction) is to expand faster than the national product, the rate of expansion varying from plan to plan. The elasticities are 1.84, 1.62, 1.50 and 1.47 in the Second, Third, Fourth and Fifth Plans respectively. It is generally agreed that within the industrial sector itself, the heavy (capital) industries will grow faster than the consumer goods industries, and for the purposes of first approximation it has been assumed that the above elasticities will hold good as between heavy industries and the industries sector as a whole. This means that the heavy industries will expand as rapidly in relation to other industries as the industries themselves with respect to the economy as a whole. On the basis of these assumptions, the following rough breakdown[35] of industrial sector is obtained:

TABLE 3.8.1

GROWTH OF OUTPUT IN INDUSTRY, 1955-56—1975-76

(million rupees)

Year	*GNP*	*Total mining and manufacturing*	*Heavy industries*	*Rest*
1955-56	108,000	19,950	1,350	18,600
1960-61	134,800	29,100	2,500	26,600
1965-66	172,600	42,500	4,360	38,140
1970-71	216,800	59,000	6,900	52,100
1975-76	282,000	85,000	11,400	73,600

That these assumptions are fairly reasonable is borne out by the fact that the output of heavy industries in 1975-76 will be about five times that in 1960-61, roughly the same ratio in which steel production is to grow, from about 6 million tons in 1961 to about 30 million tons in 1976.

In transportation, it is not possible to attempt such a breakdown as the factors affecting individual sectors are far too many and complicated to be reduced to a simple matrix of elasticities. The breakdown, therefore, will be effected at a later stage. The individual elasticities of energy consumption with respect to GNP will be as follows:

TABLE 3.8.2

RELATION BETWEEN ENERGY CONSUMPTION AND GNP BY SECTORS, 1955-75

Year	*Elasticities with respect to GNP*		
	Heavy industry	*Light industry*	*Transport*
1955-60	2.41	1.73	0.92
1960-65	2.64	1.54	0.90
1965-70	2.25	1.49	0.85
1970-75	2.16	1.39	1.00

3.9 In 1955, the effective consumption under these three categories was

Heavy Industry	7.454 mtce
Light Industry	10.464 mtce
Transport	12.087 mtce

Ignoring the effect of efficiencies for the present, we can assume elasticity of unity in each of the above sectors. Then, on the basis of figures in Table 3.8.2, the consumption in the successive plan years would be as under:

TABLE 3.9.1

ENERGY CONSUMPTION IN INDUSTRY AND TRANSPORTATION, 1955-75

(mtce)

Year	*Energy consumption*			
	Heavy	*Light*	*Transport*	*Total*
1955	7.45	10.46	12.09	30.00
1960	13.75	14.94	14.88	43.57
1965	24.00	21.40	18.70	64.10
1970	38.00	29.60	21.70	89.30
1975	63.00	42.00	28.40	133.40

3.10 The third remaining important sector, which along with industry and transportation sectors accounted for over 97 per cent of the total effective consumption in 1955, is the domestic one. Here, as incomes rise, per capita consumption for cooking, lighting and other household purposes is also expected to rise although the relative rate of expansion will be decidedly much lower. According to domestic fuel surveys[14] conducted by the NCAER in Delhi, Bombay and Calcutta, the expenditure elasticity of total net energy consumption is between 0.20 and 0.23 at lower levels of income, and lower still at higher levels, although data regarding the latter is rather scanty and inconclusive. At higher levels, there is a considerable switchover to more expensive fuels such as kerosene and electricity. These elasticities are for *total* energy only, the figures for individual energies, such as, electricity, for instance, being considerably different. For electricity, elasticity is of the order of 3.0, that is, for a ten per cent rise in household expenditure, there is a 30 per cent increase in gross consumption of electricity. In Delhi, the actual figures of consumption and income are:

TABLE 3.10.1

CONSUMPTION OF GROSS ENERGY AND ELECTRICITY BY EXPENDITURE GROUP IN HOUSEHOLDS IN DELHI CITY, 1958

(thousand kcal)

Expenditure group (Rs.)	*Total gross energy*	*Electricity*
101-200	93.7	1.4
201-350	97.2	3.0
351-600	132.1	15.7
601-1000	149.3	20.5
Above 1000	193.0	28.3

In England, too, the same type of variation was in evidence in 1949:[26]

TABLE 3.10.2

EXPENDITURE ON ELECTRICITY AND FUELS BY INCOME GROUP IN HOUSEHOLDS IN ENGLAND, 1948-49

(in £)

Households with a weekly income	*Estimated expenditure*	
	Electricity	*All other fuels*
Under 3	2.10	12.50
3-5	3.55	14.15
5-10	6.10	16.40
10-20	8.30	19.10
20 and over	16.25	19.15

Households in the last category spent only half as much again on all other fuels as the poorest households with under £ 3 incomes, but their expenditure on electricity was almost eight times that of the latter. In physical quantities, the difference must be much more marked, since in higher income brackets a good deal of the expenditure on electricity is on appliances using power at lower tariff rates. The elasticity is possibly of the order 2.5, if not more.

These domestic elasticity figures, particularly in the case of India, must be used with some reservation, for it is doubtful if they can be said to be universally valid. It is, however, obvious that as living standards rise, there must be a certain degree of increase in net energy inputs. Owing to the switchover to more expensive–and more efficient–fuels, the elasticity of *gross* consumption will naturally be lower than that of *net* consumption. It is difficult to be very precise about this, but it is fair to assume, considering all things, that the elasticity will be of the order of 0.10 to 0.15, say, 0.125. Although, strictly speaking, these are expenditure elasticities, we may assume that they would not differ very much from income elasticities.

For the country as a whole, the figure of 0.25 tce of gross consumption per capita can be accepted as a fairly accurate estimate. In Bombay, Calcutta and Delhi, it is of the order of 0.20 because of the higher proportion of commercial fuels. On the basis of income elasticity of 0.125, we have the following consumption estimates until 1975-76:

TABLE 3.10.3

ESTIMATES OF ENERGY DEMAND IN HOUSEHOLDS, 1955-56—1975-76

Year	*Per capita national income* (Rs.)	*Per capita consumption* (tce)	*Population* (million)	*Total consumption* (mtce)
1955-56	281	0.250	384	96.0
1960-61	331	0.256	408	104.5
1965-66	396	0.262	434	114.0
1970-71	460	0.268	465	129.0
1975-76	564	0.275	500	137.5

Adding the last columns in Tables 3.9.1 and 3.10.3, we have aggregate effective consumption in industry, transport and domestic sectors:

TABLE 3.10.4

ESTIMATE OF ENERGY CONSUMPTION IN INDUSTRY, TRANSPORTATION AND HOUSEHOLDS, 1955-75

(mtce)

Year	*Consumption of energy*
1955	126.0
1960	148.1
1965	178.1
1970	218.3
1975	270.9

3.11 Consumption in the remaining sectors accounted for less than 3 per cent of the total consumption in 1956, but the percentage has been steadily growing since 1950. Projections under this category cannot be effected by correlating it with, say, national income, as the relationship may not be so direct and simple. One way of doing it would be to relate it to the rest of the consumption including domestic consumption, or to consumption in industry and transport only. Between 1950 and 1956, those respective percentages have been as indicated in Table 3.11.1.

TABLE 3.11.1

ENERGY CONSUMPTION IN SERVICES AS A PERCENTAGE OF TOTAL CONSUMPTION

Year	*Effective consumption as a percentage of consumption in I+T+D*[a]	*Effective consumption as a percentage of consumption in I+T*
1950	1.50	6.90
1951	1.58	7.22
1952	1.80	8.17
1953	1.54	6.60
1954	2.28	10.05
1955	2.39	10.40
1956	2.64	10.76

[a] I = Industry; T = Transport; D = Domestic.

Barring one year, there is an unmistakable upward trend in relative consumption, although the rate of increase appears to be slackening off somewhat, particularly in the second column. By projecting this rate (with a correction of 10 per cent every five years in the second column), we obtain:

TABLE 3.11.2

ESTIMATE OF ENERGY CONSUMPTION IN SERVICES, 1960-75

Year	*A*	*B*
1960	3.82	14.04
1965	6.15	19.00
1970	9.80	25.60
1975	15.80	34.50

Applying coefficients A and B to the figures in the last column of Tables 3.10.4 and 3.9.1 respectively, we have:

TABLE 3.11.3

ESTIMATE OF EFFECTIVE ENERGY CONSUMPTION IN SERVICES, 1960-75

(mtce)

Year	'Rest' of the consumption	
	A	B
1960	5.65	6.10
1965	10.95	12.15
1970	21.40	22.80
1975	42.80	46.10

Taking 6, 12, 22 and 45 as average approximations of these, and adding them to energy figures in Table 3.10.4, we have total effective consumption in all sectors as 154.2, 190.2, 190.1, 240.3 and 315.9 mtce in the years 1960, 1965, 1970 and 1975 respectively.

3.12 To obtain net consumption figures, it is necessary to calculate the energy required for the extraction, processing and transport of energy for which an estimate of the likely proportion of primary energy has to be made. We have assumed (on the basis of an independent study made in another connection and to which reference is made later in this report) that the proportion of primary energy would increase to 40, 50, 60 and 75 per cent in 1960, 1965, 1970 and 1975 respectively, from roughly 30 per cent in 1956. On this basis, the effective primary consumption would be 61.6, 95, 144 and 237 mtce at the end of the successive plan periods. From available evidence, roughly 18-20 per cent of energy is required to make it available at the point of consumption in a readily usable form from the various points of supply, although there is no reason why this figure should not alter in the future, depending as it does on the degree of decentralization in the location of industries and the extent of shift from one fuel to another. Assuming a constant ratio of 20 per cent, this differential amount of energy would work out as 12.3, 19, 28.8 and 47.4 million tons respectively. Adding this to total effective consumption computed in para 3.11, we have total net consumption as given in Table 3.12.1.

TABLE 3.12.1

ESTIMATE OF TOTAL NET ENERGY CONSUMPTION, 1960-75

(mtce)

Year	*Total net consumption*
1960	166.4
1965	209.1
1970	269.1
1975	363.3

This is as near as we can get to the problem from the national income approach. A comparison with Table 3.6.1 indicates that these estimates lie somewhere between approaches '2' and '3', being slightly nearer to the increasing elasticities approach, which, it will be generally agreed, is a more realistic one. Although this is only a first approximation of the final estimates, it is useful as a fairly workable frame of reference and will be adopted as such in this study. A detailed summary by sectors and types of energy is tabulated in Table 3.12.2.

TABLE 3.12.2

ESTIMATE OF TOTAL ENERGY CONSUMPTION BY SECTORS AND TYPE OF ENERGY, 1955-75

(mtce)

Year	*Industrial energy*	*Transport energy*	*Domestic primary*	*Domestic secondary*	*Services & the rest*	*Total effective energy*
1955	17.91	12.09	4.3	93.7	3.1	131.1
1960	28.69	14.88	12.0	92.5	6.0	154.1
1965	45.40	18.70	18.9	95.1	12.0	190.1
1970	67.60	21.70	32.7	96.3	22.0	240.3
1975	105.00	28.40	58.5	79.0	45.0	315.9

(TABLE 3.12.2 *continued.*)

Year	*Energy lost in processing and trans-porting energy*	*Total net energy*	*Total pri-mary*	*Total secon-dary*	*Ratio of P : S*	*Ratio of Domestic Primary to Total Primary*
1955	6.3	137.4	43.7	93.7	0.466	0.098
1960	12.3	166.4	73.9	92.5	0.8	0.162
1965	19.0	209.1	114.0	95.1	1.2	0.166
1970	28.8	269.1	172.8	96.3	1.8	0.191
1975	47.4	363.3	284.3	79.0	3.6	0.206

The last two columns are interesting. They show that while the ratio of primary to secondary energy will go up sharply from about 0.5 to 3.6, the ratio of domestic primary to total will just about double itself during this period. Within the domestic sector itself, however, although the amount of secondary energy would appear to be only slightly declining, it will have, in relative terms, come down from about 96 per cent in 1955 to 57.5 per cent in 1975. This is a substantial decrease illustrating the extent of commercialization of domestic energy likely to be attained in the coming years.

3.13 It is now possible to proceed further and have a breakdown by type of energy. Of all the forms in which energy enters the productive economic processes, electricity is the most refined and one that has a close relationship with a particular sector of the economy, viz. industry. As high a percentage as 75 is consumed in industry which, as far as electricity is concerned, can therefore be said to be the pace-setter for general electricity consumption. It is also for this reason that electricity is commonly regarded as a more accurate index of industrial growth than total energy consumption. This aspect will be considered in the next section which deals mainly with electricity projections.

CHAPTER IV

DEMAND FOR ELECTRICITY

4.1 Electricity constitutes an advanced form of energy and its development has not only made it possible to take advantage much more intensely of some renewable sources like water, but it has also created a number of new uses for all kinds of energy in the production and social processes. Industrial development, mechanization and urban progress are virtually a function of electricity supplies. Therefore, consumption of electricity is a very significant indicator, both as a means of appraising specific energy situations and the general economic state of countries.

There are certain characteristics which distinguish electricity consumption from the general energy situation. While only about a third of the total net energy is consumed as a factor in production (mainly in the industrial and·transportation sectors) over three-quarters of the total electricity consumption is in the productive sectors, only a small proportion being consumed by households and other services. Actually, industry, as has been mentioned earlier, is the pace-setter in electricity production, the use of electricity in other sectors arising more or less as a by-product of the main use. The consumption of electricity is, for this reason, a more significant index of industrial production rather than of per capita incomes, for, while modern industry is virtually impossible without electricity, it is possible to increase gross national product, within reasonable limits, through other than industrial expansion. If per capita incomes are plotted against per capita consumption of electricity (Fig. 2), it will be found that countries with similar consumption of total energy per unit of product have dissimilar unit consumption of electricity. Thus, while in the higher consumption group, U.K. requires about 1 kWh per dollar, Canada needs 2.3; among countries in the intermediate group, Denmark requires 0.5 while Norway needs 5.9; among lower consumption groups, the variation is equally marked.

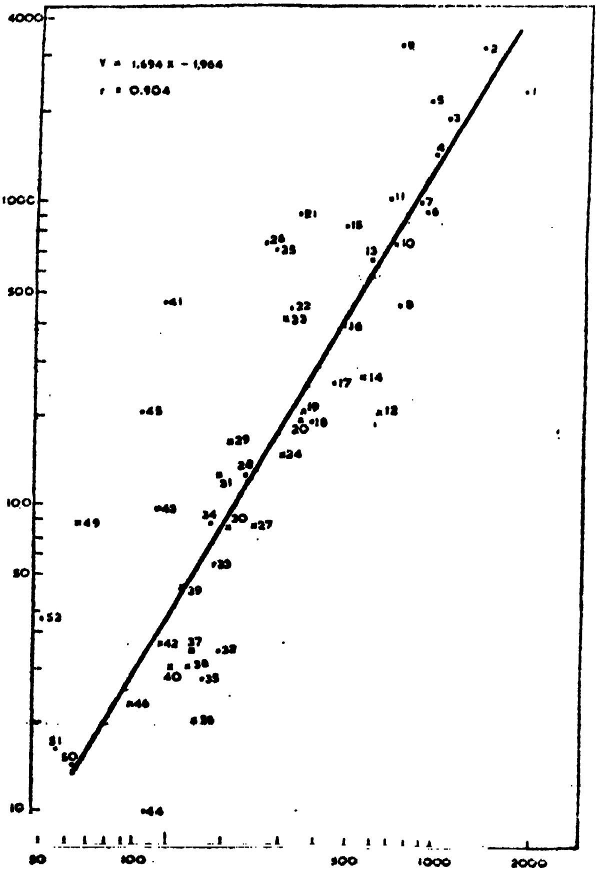
4.2 Demand for electricity not only tends to grow more rapidly than that of other types of energy but also at a much higher rate than the net national output. This is because electricity with its high efficiency of

FIGURE 2

CORRELATION BETWEEN PER CAPITA CONSUMPTION OF ELECTRICITY AND GROSS PER CAPITA PRODUCT, AVERAGE — 1949-51 (LOGARITHMIC SCALE)

Y = Total per capita consumption of electricity (kWh)

X = Gross per capita product (dollars at 1950 prices)



X = Latin American countries

• = Other countries

NOTE: For order of countries see list following Figure 1.

SOURCE: *Energy in Latin America*, United Nations, 1957.

utilization is constantly replacing other forms of energy as the main source of mechanical power. This means that there is a constant increase in consumption of electricity per unit of national product. In India, the number of kWh per rupee of net output has increased from 0.0766 in 1950 to 0.110 in 1956. In other countries, the relative rate of growth can be judged from the fact that while GNP increases at the rate of about 3–4 per cent annually, electricity consumption usually doubles itself in about ten years.[37]

This is reflected in the relationship between per capita incomes and per capita electricity consumption, which may be used as a 'first approximation' method for projecting demand in the future. The elasticity is about 1.7, that is, for a 10 per cent rise in per capita income there is a 17 per cent rise in per capita consumption. In 1955, effective per capita consumption was 23.4 kWh which, on the above basis, can be expected to grow as follows:

TABLE 4.2.1

ESTIMATE OF PER CAPITA CONSUMPTION OF ELECTRICITY, 1955-75

Year	*Per capita income* (Rs.)	*Per capita consumption* (kWh)	*Population* (million)	*Total effective consumption* (million kWh)
1955	281	23.4	384	8,959
1960	331	30.5	408	12,500
1965	396	40.7	434	17,700
1970	466	53.0	465	24,600
1975	564	72.0	500	36,000

The figure of 1.7 is obviously low for Indian conditions as the relative growth of the electricity-intensive industrial sector within the economy in India is much faster than in more developed and mature economies. Between 1950 and 1956, while net per capita income increased by 15 per cent, per capita consumption of electricity rose through almost 50 per cent, giving an elasticity of about 3.33, about twice as high as in other countries. Assuming a progressively diminishing order of elasticities (to allow for the decelerating pace of development in the later stages of the Plan),[38] we get the results as in Table 4.2.2.

TABLE 4.2.2

ESTIMATE OF PER CAPITA CONSUMPTION OF ELECTRICITY (VARYING ELASTICITIES), 1955-75

Year	Per capita income (Rs.)	Elasticity	Per capita consumption (kWh)	Population (million)	Total effective consumption (million kWh)
1955	281		25.4	384	8,959
		3.35			
1960	331		38.9	408	15,900
		3.00			
1965	396		61.8	434	26,800
		2.50			
1970	466		89.0	465	41,400
		2.00			
1975	564		126.0	500	63,000

4.3 Another rough yardstick which is often used for measuring demand is based on assumptions relating to 'doubling periods'. During the Second Plan, the doubling period is expected to be five and a half years instead of the five years assumed during the formulation of the Plan.[39] During the Fifth Plan period, the doubling period may be expected to be reduced to ten years,[40] the period in between being six and eight years in the Third and Fourth Plans respectively. These correspond to ratios of growth of 13.4, 12.3, 9.0 and 7.2 compounded annually during the Second, Third, Fourth and Fifth Plans respectively. On these assumptions adopted by the Natural Resources Division of the Planning Commission for its projections,[41] the following estimates of demand have been made.

TABLE 4.3.1

ESTIMATE OF AGGREGATE DEMAND FOR ELECTRICITY (DOUBLING PERIOD BASIS), 1956-61—1971-76

Period	Doubling period (years)	Compounded annual rate of growth (per cent)	Effective consumption during the last year of the period (million kWh)
1956-61	5½	13.4	16,900
1961-66	6	12.3	30,400
1966-71	8	9.0	46,700
1971-76	10	7.2	66,500

These differ only slightly from those in Table 4.2.2 and may be assumed to be fairly reasonable, under the circumstances. Their reliability can be tested through the synthetic method, that is, by assessing individual sectoral requirements and summating them to obtain overall requirements.

4.4 Since industry is the main consumer of electricity, the relationship between the index of industrial production and power generation can provide a reasonable basis for assessing future power requirements. The indices are given in Table 4.4.1.

TABLE 4.4.1

INDUSTRIAL PRODUCTION AND EFFECTIVE ELECTRICITY CONSUMPTION, 1950-56

(1951 = 100)

Year	*Index of industrial production*	*Index of effective consumption*
1950	89.6	87.5
1951	100.0	100.0
1952	103.6	106.8
1953	105.6	117.2
1954	112.9	128.0
1955	122.1	143.4
1956	133.0	158.5

The correlation coefficient (0.99) is high not only for India but for almost all the countries (with very few exceptions) and suggests that the degree of precision in estimating power generation in terms of industrial production is high.[42] The elasticity is 1.77, and by adopting this, we obtain the following indices of effective consumption in relation to production indices.[43]

TABLE 4.4.2

ESTIMATE OF TOTAL EFFECTIVE CONSUMPTION OF ELECTRICITY, 1955-75

Year	*Index of industrial production* (1951 = 100)	*Index of total effective consumption* (1951 = 100)	*Total effective consumption* (million kWh)
1955	122.1	143.4	8,959
1960	185.0	273.0	17,000
1965	285.0	535.0	33,600
1970	420.0	985.0	61,500
1975	610.0	1,730.0	108,000

These are higher than the corresponding results in Tables 4.2.2 and 4.3.1 which means that the earlier assumptions as regards doubling periods etc. were somewhat conservative. A doubling period of ten years corresponds to an annual rate of industrial growth of about 4.25 per cent which is a normal rate for countries with highly developed industrial economies. According to our calculations, the rate of growth in India will be between 8 and 9 per cent annually, that is, almost double the rate of growth corresponding to a ten-year doubling period. It is, therefore, to be expected that the doubling period in India will continue to be five years as long as the rate of industrial growth is sustained at this high pace. The three results are summarized below:

TABLE 4.4.3

SUMMARY OF ESTIMATES OF CONSUMPTION OF ELECTRICITY, 1955-75

(million kWh)

Approach	1955	1960	1965	1970	1975
Deminishing elasticities	9,000	15,900	26,800	41,400	63,000
Increasing 'doubling' period	9,000	16,900	30,400	46,700	66,500
Industrial index	9,000	17,000	33,600	61,500	108,000

4.5 It is now necessary to obtain broad sectoral breakdowns for as many sectors as possible, beginning, of course, with the industrial sector. There is, in this connection, one aspect to be noted: because electrical energy is used principally as a source of mechanical power, it is used relatively more in light industries than in heavy industries.[44] The coefficient of electrification—that is the number of kWh per unit input of total energy—is thus higher in the lighter industries so that in projecting demand for electricity, the relative growth of these two sub-sectors within the industry is a major factor to be reckoned with. The coefficients for the two types of industries are indicated in Table 4.5.1.

In interpreting these results one must guard against the fact that while the statistics of electricity consumption are generally fairly accurate, the same cannot be said of either coal or petroleum consumption in industries in the estimation of which a good deal of guesswork is involved. None-

TABLE 4.5.1

COEFFICIENT OF ELECTRIFICATION IN INDUSTRY, 1950-56

	1950	1951	1952	1953	1954	1955	1956
Effective coefficient (kWh/tce)							
Heavy industry (H)	190	219	230	253	260	288	307
Light industry (L)	287	334	363	357	382	409	407
L/H	1.51	1.53	1.52	1.41	1.47	1.42	1.35
Aggregate coefficient	247	287	309	313	336	360	366
Annual percentage increase		16	8	1.5	7	7	2

theless, it is clear that the coefficient of electrification in light industries is about 30 to 50 per cent higher than in heavy industries. Secondly, the rate of increase would appear to be tapering off, although it would be difficult to quantify it precisely.

4.6 From the available data of past few years, the elasticity between the index of industrial production and the index of industrial electricity consumption[45] is of the order of 1.80 and, on this basis, the following indices for the latter are obtained:

TABLE 4.6.1

ESTIMATE OF INDEX OF INDUSTRIAL ELECTRICITY, 1955-75

Year	*Index of industrial production*	*Index of electricity in industry*
1955	122	100
1960	185	193
1965	185	380
1970	420	765
1975	610	1,280

On the basis of these indices, the consumption in absolute values would work out as in Table 4.6.2.

TABLE 4.6.2

ESTIMATE OF CONSUMPTION OF ELECTRICITY IN INDUSTRY, 1955-75
(million kWh)

Year	*Effective consumption in industry*
1955	6,445
1960	12,400
1965	24,500
1970	45,500
1975	82,500

A breakdown as between light and heavy industries is attempted later in Chapter VII.

4.7 The next important item of consumption is in households. Total electricity consumed—both for lighting and fans, and domestic heat and power—has averaged about 10 per cent of the total effective power, the lighting complement increasing at the rate of almost exactly 50 per cent in five years (1951-56) and the rest doubling in five years. If these rates are maintained, the consumption would be as follows:

TABLE 4.7.1

ESTIMATE OF DEMAND FOR ELECTRICITY IN HOUSEHOLDS, 1955-75
(million kWh)

	1955	1960	1965	1970	1975
Domestic lighting and fans	693	1,040	1,560	2,340	3,510
Domestic heat and small power	157	314	628	1,256	2,512
Total	850	1,354	2,188	3,596	6,022

Information regarding electricity consumption (for domestic uses) in relation to per capita incomes is so fragmentary that it is doubtful whether it can be made use of in effecting reliable projections. The elasticity varies according to the income level, increasing sharply at lower levels and then undergoing gradual reduction, probably remaining more or less stationary at very high income levels near the point of saturation. In India, there is virtually no electricity in villages, only about 1.5 to 2 per cent of the total having been electrified by 1955.[46] The number of units per head of urban population[47] have increased from 4.690 kWh in 1945 to 12.365 kWh in 1956, and if this is correlated with per capita incomes, the regression equation can be used to give figures of future consumption as shown below:

TABLE 4.7.2

ESTIMATE OF DEMAND FOR ELECTRICITY IN URBAN HOUSEHOLDS, 1955-75

	1955	1960	1965	1970	1975
Per capita income (Rs.)	281	331	396	466	562
Per capita (urban) consumption (kWh)	11.6	16.0	22.0	30.0	44.0
Total urban population (million)	73.2	86.5	106.0	126.0	148.0
Total electricity consumption (million kWh)	850	1,384	2,332	3,780	6,512

These figures are slightly higher than those arrived at empirically in Table 4.7.1 and are probably more representative of the actual trends. The figures refer to urban consumption only and cognizance has to be taken of the growth of electrification in rural areas which is insignificant at present, but is bound to be substantial in years to come. In 1960, about 3 per cent of the total rural population is to be supplied with electricity[48] and there are indications that the percentage will be doubled every five years. Per capita consumption in villages will, however, be much lower than in urban areas, since per capita incomes in villages will be on an average about half of those in towns and cities.[49] According to Table 4.7.2, a doubling of per capita income results in quadrupling per capita electricity consumption; on the basis of this relationship, the consumption in rural areas would be as under:

TABLE 4.7.3

ESTIMATE OF DEMAND FOR ELECTRICITY IN RURAL HOUSEHOLDS, 1955-75

	1955	1960	1965	1970	1975
Electrified rural population (million)	4.5	9.6	19.7	40.7	84.5
Per capita consumption of electricity (kWh)	3.0	4.0	5.5	7.5	11.0
Total rural consumption (million kWh)	13.5	38.4	108.5	306.0	929.5

Adding this to the last column in Table 4.7.2, we obtain total domestic electricity consumption as 1,422 (in 1960), 2,440 (1965), 4,086 (1970) and 7,440 (1975) million kWh.

4.8 The use of electricity in households is essentially a function of the degree of urbanization and so is its use in public services (for street lighting and in water works) and commercial services. It is, therefore, not at all surprising that there is a close correlation between consumption in households and services as will be seen from the following:

TABLE 4.8.1

CORRELATION BETWEEN ELECTRICITY CONSUMPTION IN HOUSEHOLDS AND SERVICES, 1950-56

(million kWh)

	1950	1951	1952	1953	1954	1955	1956
Domestic (D)	524	595	629	690	759	850	934
Services (S)	558	611	630	661	808	905	980
S/D	1.07	1.03	1.00	0.96	1.06	1.06	1.05

Moreover, the consumption in services would appear to be on an average about 5 per cent higher than in households, and on this basis, the future estimates of 'services' consumption can be worked out as under:

TABLE 4.8.2

ESTIMATE OF CONSUMPTION OF ELECTRICITY IN SERVICES, 1955-75

(million kWh)

Year	*'Services' consumption*
1955	905
1960	1,450
1965	2,450
1970	3,970
1975	6,850

4.9 The only two remaining items which together accounted for less than 7 per cent of the total effective consumption in 1956 are traction and irrigation. The percentage of electrical energy consumed under irrigation (i.e. for pumping etc.) is, as a rule, and for obvious reasons, far higher in regions served by hydro power (as in Madras) than in those drawing upon thermal electricity.[50] (The coefficient of rural electrification is also very closely related to hydro power generation). With the increasing pace of hydro power development expected in the next few decades,[51] it can be assumed that the rate of growth of irrigation by electric pumps will also be stepped up and will, in any case, be faster than in the immediate past. Between 1951 and 1956, the consumption rose through 55 per cent from 203 to 316 million kWh. Assuming a consecutive rate of increase of 100, 90, 80 and 70 per cent in the succeeding plan periods,[52] we have:

TABLE 4.9.1

ESTIMATE OF DEMAND FOR ELECTRICITY FOR IRRIGATION, 1955-75

(million kWh)

Year	*'Irrigation'*
1955	255
1960	510
1965	970
1970	1,750
1975	3,000

4.10 In railway traction, electrification is one of at least two alternatives of speeding up traffic, and the choice will ultimately depend upon a number of factors including (1) the nature and density of developing traffic in various regions, (2) cost of fuels and (3) the relative capital costs of dieselization and electrification. From a long-term point of view, however, electrification would appear to be better suited to Indian conditions than dieselization as the country is more favourably situated with regard to low grade coal (which can be used with the maximum efficiency in thermo-electric stations) than to petroleum.[53] The precise rate at which railway electrification will develop is difficult to forecast with any degree of accuracy, for it is not directly related to the economy except at a micro level and any overall estimate can only be a matter of guesswork. It has been suggested by a Railway fuel committee[54] that at least 30 per cent of traction capacity would have to be electrified by 1975-76. Since the efficiency of a steam locomotive is of the order of 4.5 per cent and that of electric traction about 13 to 14 per cent, this means that in terms of *gross energy*, the energy requirements of electric traction will be about 10 per cent of the total. In 1955, electric traction accounted for about 3.3 per cent of the total energy consumption by the railways. We can, therefore, visualize the future pattern of electric traction somewhat on the following lines:

TABLE 4.10.1

ESTIMATE OF DEMAND FOR ELECTRICITY IN TRACTION, 1955-75

	1955	1960	1965	1970	1975
Total energy consumption by railways (mtce)	12.35	16.0	22.0	28.00	35.0
Proportion of 'electric traction' energy (per cent)	3.30	5.0	6.8	8.40	10.0
Total 'electric traction' energy (mtce)	0.42	0.8	1.5	2.36	3.5
Total 'electric traction' (million kWh)	515.00	1,080.0	2,180.0	3,640.00	5,850.0

The figures in the first row will have to be confirmed through detailed studies[55] before the figures in the last row can be accepted as final. They can, however, be accepted as approximate estimates for preparing an electricity balance framework on the lines of total energy framework in Table 3.12.2. The figures include consumption for carrying coal also and have to be reduced to 'effective' energy by applying an appropriate coefficient. At present, about a third of the traffic carried by the railways is coal and by 1975 it is likely that coal will constitute at least one half of the total rail traffic, if not more.[56] The 'effective' energy equivalent of electric traction will thus be:

TABLE 4.10.2

ESTIMATE OF DEMAND FOR EFFECTIVE ELECTRICITY IN TRACTION, 1955-75

(million kWh)

Year	*Effective 'electric traction'*
1955	515
1960	920
1965	1,520
1970	2,250
1975	3,170

4.11 The sectoral breakdowns of effective electricity obtained in the foregoing paragraphs are tabulated below:

TABLE 4.11.1

ESTIMATE OF DEMAND FOR ELECTRICITY BY SECTORS, 1955-75

(million kWh)

	1955	1960	1965	1970	1975
Agriculture (irrigation)	255	510	970	1,750	3,000
Industry	6,445	12,400	24,500	45,500	82,500
Domestic					
Urban: Light & fans	679	1,062	1,665	2,460	3,800
Heat	157	322	667	1,320	2,712
Rural	14	38	108	306	929
Total Domestic	850	1,422	2,440	4,086	7,441
Services	905	1,450	2,450	3,970	6,850
Transport	515	920	1,520	2,250	3,170
Total effective electricity	8,970	16,702	31,880	57,556	102,961
Industrial index approach	9,000	17,000	33,600	61,500	108,000

The agreement between the last two rows is fairly close which indicates that the assumptions involved are substantially valid, and the results may, therefore, be considered reasonably accurate. To incorporate them in the total energy framework, it is necessary to convert them into coal equivalent. The conversion coefficient, a measure of the thermal efficiency of electricity generation, will naturally vary from year to year. The amount of coal utilized to produce 1,000 kWh of electricity has dropped from 0.915 tons in 1950 to 0.785 tons in 1956 which corresponds to an efficiency increase of about 2 per cent annually.[57] In England, the consumption of coal per kWh fell from 2.5 lbs. to 1.5 lbs. between 1924 and 1937, and is currently at the level of about 1.24 lbs. This apparently slow rate of decrease during the last two decades is due to the fact that, although absolute thermal efficiencies have been uniformly improving (particularly during the post-war years) the use of low grade coal in power stations has tended to step up the coal requirements by weight. A similar situation is also likely to develop in this country with the result that the conversion coefficient may not drop at the same rate as in the past during the next two decades. The following coefficients have been adopted in this study:

TABLE 4.11.2

CONVERSION COEFFICIENTS FOR ELECTRICITY, 1955-75

Year	tce *per* 1,000 kWh
1955	0.785
1960	0.740
1965	0.695
1970	0.650
1975	0.600

The electricity balance-sheet (provisional) in terms of coal equivalent will thus be as follows:

TABLE 4.11.3

BALANCE-SHEET OF DEMAND FOR ELECTRICITY, 1955-75

(thousand tce)

	1955	1960	1965	1970	1975
Agriculture	200	378	674	1,136	1,800
Industries	5,080	8,920	17,000	29,600	49,500
Domestic					
Lighting	542	815	1,233	1,800	2,840
Heat	123	238	462	857	1,625
Service	607	1,072	1,700	2,580	4,110
Transport	405	680	1,055	1,460	1,900
Total	6,957	12,103	22,224	37,433	61,775

These figures refer to effective energy only and the losses in processing and transmission have to be taken into account for working out gross energy consumption. But some more information—net coal output and petroleum refining capacities—is necessary before this can be done, and will therefore be taken up at a later stage.

4.12 Having separated the electricity complement from total energy, it is now possible to obtain a sectoral breakdown of the remaining energy by deducting the figures in Table 4.11.3 from the corresponding ones in Table 3.12.2.

TABLE 4.12.1

BALANCE-SHEET OF DEMAND FOR NON-ELECTRICAL ENERGY, 1955-75

(thousand tce)

	1955	1960	1965	1970	1975
Industry	12,830	19,770	28,400	38,000	55,500
Domestic					
Primary	3,635	10,947	17,107	30,043	54,035
Secondary	93,700	92,500	95,100	96,300	79,000
Transport	11,685	14,200	17,645	20,240	26,500
Services and the rest[a]	2,293	4,550	9,626	18,284	39,090
Total	124,143	141,967	167,878	202,867	254,125
Total Primary	30,443	49,467	72,778	106,567	175,125

[a] Including agriculture.

These non-electricity requirements will be met from coal and petroleum, the contribution of each varying according to the sector in which they are used and the relative economic advantages of their utilization. In industry and households, the requirements represent mostly heat since the power requirements in either of these sectors have been taken care of by electricity. In transportation, they represent mobile power through heat, that is, steam or diesel traction on the railways, and motive power for road transport, aviation and shipping. The difficulty in separating the two sources of energy, viz. coal and petroleum, stems from the fact that they are in many ways substitutible, and the factors which promote the use of one in preference to another are so varied and at times so intangible that it is almost impossible to foresee them with a degree of clarity sufficiently adequate to enable one to assess their impact on the energy situation in precise, quantitative terms. In households, for instance, heat for cooking and other household purposes can be obtained either from coal or kerosene, and although price is one of the factors to be taken into consideration, it is not the only factor governing their relative consumption. One way of overcoming this difficulty is to isolate the areas of consumption in which the two sources are not substitutible in practice (although in theory all forms of energy are, no doubt, ultimately interchangeable). The use of kerosene for lighting in villages is one such instance. In theory, it is possible to supply either electricity (from thermal stations) or coal gas for the lighting requirements of rural areas, but having decided upon certain targets of rural electrification, it is reasonable to assume that the non-electrified villages will, to a large extent, draw upon kerosene for their lighting needs. Similar assumptions, not all of which are as straightforward, can help in the unravelling of energy streams and in establishing individual projection estimates. These individual estimates by type of energy can then be aggregated to give total demand. Projections of energy demand by means of a selective analysis of individual energy-consuming sectors is a more accurate way of ascertaining the distribution of total energy consumption by types of fuel and of examining closely the possibilities of replacing one fuel by another (vide para 2.2). These results can then be compared with those obtained by the 'overall' method and, if necessary, suitably adjusted.

CHAPTER V

ENERGY IN HOUSEHOLDS

5.1 It will be seen from Tables I and II that the primary constituent of total energy consumed in households is extremely small and was as low as 5 per cent in 1955. Of the total consumption of about 98 mtce, 2.4 mtce was used in lighting, and of the rest, only 2.2 mtce of domestic heat was derived from coal and petroleum products. The secondary constituent is made up of firewood, charcoal, dung and agricultural wastes and, until recently, their individual contributions were largely a matter of speculation. It has now been estimated[14] that the source of heat in households in 1956 was as indicated in Table 5.1.1. It is generally realised that the current pattern of consumption is extremely wasteful and should be altered in the interests of national economy as the economic consequences of burning cow-dung and firewood are, and will continue to remain extremely serious. The problem of substitution, however, is rather complicated by the multiplicity of factors involved, and deserves a separate study. Some of the aspects of this problem and their bearing on individual fuel estimates are considered here.

TABLE 5.1.1

SOURCE OF HEAT[a] IN HOUSEHOLDS, 1955

(mtce)

Fuel	*Urban*	*Rural*	*Total*
Primary			
Coal	2.0	..	2.0
Electricity	0.2	..	0.2
Kerosene	0.3	..	0.3
Secondary			
Dung	4.0	35.0	39.0
Firewood: Solid[b]	8.5	23.5	32.0
Waste[c]	5.0	18.5	23.5
Total	20.0	77.0	97.0

[a] that is, excluding energy used in lighting, etc.

[b] including charcoal. [c] twigs, bagasse, etc.

SOURCE : *Domestic Fuels in India*, NCAER, 1959, p. 17.

5.2 The use of kerosene for lighting is widespread in India, particularly in villages, its use as a domestic fuel for cooking being restricted largely to urban areas. This is, however, a very general statement and there are important variations from the norm. From the NCAER fuel surveys and from other evidence, it appears that per capita consumption of kerosene in India is as indicated in Table 5.2.1:

TABLE 5.2.1

CONSUMPTION OF KEROSENE IN URBAN AND RURAL HOUSEHOLDS, 1958

(lbs|month)

Area	*Consumption per capita*
Delhi	4.46
Madras	0.76
Bombay	5.26
Calcutta	1.20
Towns above 50,000 population	1.16
Towns with 15,000-50,000 population	1.56
Towns below 15,000 population	1.22
Rural	0.72

The proportion of kerosene used for cooking varies from place to place, and is the highest in Bombay (90 per cent), followed by Delhi (73 per cent), Calcutta (50 per cent) and Madras (33 per cent). In small towns, the proportion is likely to be lower although no definite information is available on that point. Assuming that it will go on decreasing with the size of the township, we may place it at 25, 15 and 10 per cent for the three types of towns mentioned in the table. In rural areas, virtually all the kerosene is used for lighting. On this basis, the proportion used for lighting will be as shown in Table 5.2.2.

TABLE 5.2.2

CONSUMPTION OF KEROSENE FOR LIGHTING IN URBAN AND RURAL HOUSEHOLDS, 1953

(lbs|month)

Area	*Consumption per capita*
Delhi	0.124
Madras	0.507
Bombay	0.520
Calcutta	0.600
Towns above 50,000 population	0.870
Towns with 15,000-50,000 population	1.330
Towns below 15,000 population	1.110
Rural	0.720

It will be seen that there is a sizable demand for kerosene for lighting even in urban areas including cities, and that in smaller towns it is generally higher on a per capita basis than in villages. It must be emphasized that these are very rough estimates indicative more of the relative order of magnitudes than of actual consumption. For the purpose of this study, the following values of consumption have been adopted (1955):

TABLE 5.2.3

CONSUMPTION OF KEROSENE FOR LIGHTING AND HEAT IN INDIA, 1958

(lbs|month)

Area	*Consumption per capita*		
	Lighting		*Heat*
Cities	0.34	0.78	0.35
Towns	0.84		
Rural	0.56		Nil

It is reasonable to assume that the consumption per head will decrease in urban areas with increasing urbanization although perhaps there will still be peripheral urban communities relying upon kerosene for their lighting needs. As a rough conservative estimate we shall assume that there will be a 10 per cent fall in per capita consumption every five years, so that total urban requirements of kerosene for lighting will work out as follows:

TABLE 5.2.4

ESTIMATE OF DEMAND FOR KEROSENE FOR LIGHTING IN URBAN AREAS, 1955-75

	1955	1960	1965	1970	1975
Per capita consumption (lbs/month)	0.78	0.702	0.632	0.569	0.512
Urban population (million)	73.2	86.5	106.0	126.0	148.0
Total annual consumption (tons)	306,000	326,000	360,000	384,000	405,000

In rural areas, a similar estimate can be made on the assumption that consumption per head will increase by 10 per cent every five years. (It will be seen from Table 5.2.2 that the consumption in towns is about 1.5 times that in villages.)

TABLE 5.2.5

ESTIMATE OF DEMAND FOR KEROSENE FOR LIGHTING IN NON-ELECTRIFIED RURAL AREAS, 1955-75

	1955	1960	1965	1970	1975
Rural population (million)	310.80	321.50	328.00	339.00	352.00
Population served by electricity (million)	4.50	9.60	19.70	40.70	84.50
Net rural population depending on kerosene (million)	306.30	311.90	308.00	298.30	267.50
Per capita consumption of kerosene (lbs/month)	0.56	0.62	0.68	0.75	0.82
Total annual consumption of kerosene (tons)	917,000	1,035,000	1,120,000	1,200,000	1,175,000

In addition to this, we have to allow for the use of kerosene by the population in the second row where the consumption will be, on per capita basis, slightly less than the amounts assumed in the fourth row.

TABLE 5.2.6

ESTIMATE OF DEMAND FOR LIGHTING IN ELECTRIFIED RURAL AREAS, 1955-75

	1955	1960	1965	1970	1975
Population served by electricity (million)	4.50	9.60	17.70	40.70	84.50
Per capita consumption of kerosene (lbs/month)	0.55	0.55	0.55	0.60	0.65
Total annual consumption (tons)	13,200	28,300	58,000	131,000	295,000

Adding up the total, we have:

TABLE 5.2.7

ESTIMATE OF DEMAND FOR KEROSENE FOR LIGHTING IN URBAN AND RURAL AREAS, 1955-75

(tons)

Year	*Consumption of kerosene for lighting*
1955	1,236,200
1960	1,389,300
1965	1,538,000
1970	1,715,000
1975	1,875,000

5.3 Estimates of demand of primary energy for domestic consumption (vide Table 3.12.2) were derived on the assumption that the proportion of primary energy would increase to 40, 50, 60 and 75 per cent of the total in 1960, 1965, 1970 and 1975 respectively from roughly 30 per cent in 1956. As far as 1960 is concerned, this is clearly an over-estimate as it is most unlikely that the consumption of domestic primary energy would reach 12 mtce by that year. A more modest aim would be to plan for the total replacement of secondary energy in urban areas by primary energy by 1975. The requirements of urban population will grow as given in Table 5.3.1.[59]

TABLE 5.3.1

ESTIMATE OF DEMAND FOR ENERGY IN URBAN HOUSEHOLDS, 1955-75

Year	*Total urban population* (million)	*per capita consumption* (tons)	*Total requirements* (mtce)
1955	73.2	0.250	18.3
1960	86.5	0.256	22.1
1965	106.0	0.262	27.8
1970	126.0	0.268	33.7
1975	148.0	0.275	40.6

These are gross energy requirements for heat, i.e. excluding lighting. Deducting heat from electricity, net domestic heat (non-electric) requirements would be as follows:

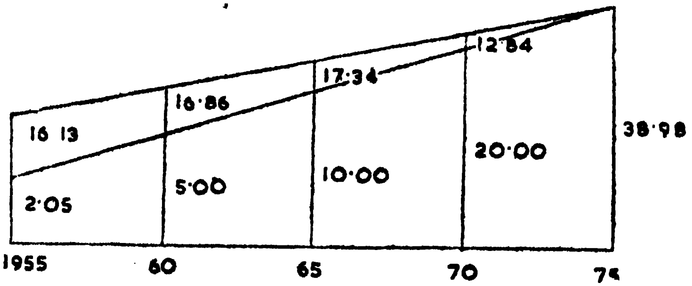
TABLE 5.3.2

ESTIMATE OF DEMAND FOR NON-ELECTRIC HEAT IN URBAN HOUSEHOLDS, 1955-75

(mtce)

	1955	1960	1965	1970	1975
Total requirements of domestic energy (heat)	18.30	22.10	27.80	33.70	40.60
Domestic heat from electricity	0.12	0.24	0.46	0.86	1.62
Net domestic heat (non-electric)	18.18	21.86	27.34	32.84	38.98

In 1955 only 2.05 mtce of domestic heat were supplied by coal and petroleum, of which about 0.2 mtce were contributed by the latter. The gap, therefore, is about 16 mtce which was made up by the import of secondary fuels into the area. If we assume that by 1975 all the domestic heat requirements will be met by primary energy, then the gap will progressively close in the following manner:



It will be seen that the gap will remain more or less constant at the present level until about 1965 when it will begin to decline. In 1955, consumption of kerosene used as domestic heat was 0.35 pounds per month per head of urban population, total consumption being 200,000 tce per year. This, it will be seen, is about 6.4 per cent of the total primary heat, and if we assume this ratio to remain constant—although there are no valid grounds for this assumption—future demand would work out as follows:

TABLE 5.3.3

ESTIMATE OF DEMAND FOR KEROSENE FOR DOMESTIC HEAT
1955-75—BASIS 'A'
(tce)

Year	*Estimated consumption of kerosene (heat)*
1955	200,000
1960	382,000
1965	764,000
1970	1,528,000
1975	2,300,000

This is one way of estimating the demand. A great deal will depend on the nature and quality of primary fuels developed in the future for domestic use, for not all of them can be said to perfect substitutes for each other. Soft coke, for instance, is a poor substitute for kerosene, although, if the price is favourable it may be assumed to be interchangeable at par with the latter. As far as kerosene is concerned, available evidence indicates that its use as a source of domestic heat is as a rule more marked in middle-income group households where it is fast replacing charcoal and has always been preferred to soft coke. Coal gas, on the other hand, is preferred to kerosene, and so is LPG (bottled refinery gas) despite its relatively high cost. We may, therefore, assume that (1) expansion of coal gas and LPG supplies will lead to a decline in demand for kerosene; and (2) expansion of soft coke supplies will not materially affect the demand for kerosene. It is, however, extremely difficult to quantify these assumptions as the necessary statistical information is just not available.

Another approach would be to assume that (1) as a result of the increase in the number of the middle-income group households and (2) an increase in their per capita kerosene consumption consequent on a rise in their living standards, the overall per capita consumption will double every five years as long as the gap remains constant and then decline by 25 per cent quinquennially. This assumption would lead to the following results:

TABLE 5.3.4

ESTIMATE OF DEMAND FOR KEROSENE FOR DOMESTIC HEAT, 1955-75—BASIS 'B'

(tce)

Year	*Consumption*
1955	200,000
1960	475,000
1965	1,154,000
1970	1,030,000
1975	906,000

This appears more realistic as there is no reason to suppose that the consumption will go on increasing for ever. A third method would be to assume, in conformity with past trends, that the consumption will double every five years until 1965 and then increase by 50 per cent until 1975. This will give the following estimates:

TABLE 5.3.5

ESTIMATE OF DEMAND FOR KEROSENE FOR DOMESTIC HEAT, 1955-75—BASIS 'C'

(tce)

Year	*Consumption*
1955	200,000
1960	400,000
1965	800,000
1970	1,200,000
1975	1,800,000

This appears to give figures half way between those derived earlier. The results are summarized in Table 5.3.6, the last column giving the average of all three:

TABLE 5.3.6

SUMMARY OF ESTIMATES OF DEMAND FOR KEROSENE FOR DOMESTIC HEAT, 1955-75

(tce)

Year	*Consumption*			*Mean*
	Basis 'A'	*Basis 'B'*	*Basis 'C'*	
1955	200,000	200,000	200,000	200,000
1960	382,000	472,000	400,000	418,000
1965	764,000	1,154,000	800,000	906,000
1970	1,528,000	1,030,000	1,200,000	1,253,000
1975	2,300,000	906,000	1,800,000	1,668,000

No great degree of accuracy is claimed for these estimates. They indicate the order of magnitudes (and its range of variation) rather than absolute quantities. Total consumption, including lighting, will be as follows:

TABLE 5.3.7

ESTIMATE OF DEMAND FOR KEROSENE FOR HEAT AND LIGHTING IN HOUSEHOLDS, 1955-75

(mtce)

Year	*Total consumption*
1955	2.06
1960	2.50
1965	3.16
1970	3.82
1975	4.48

5.4 Estimates of demand for all types of domestic energy can now be summarized as indicated in Table 5.4.1 and as illustrated in Fig. 3 and Fig. 4.

TABLE 5.4.1

ESTIMATE OF DEMAND FOR HOUSEHOLD ENERGY FOR LIGHTING AND HEAT BY TYPE OF ENERGY, 1955-75

(mtce)

Year	*Urban population*						
	Electricity		*Kerosene*		*Coal*	*Secondary*	*Total*
	Lighting	*Heat*	*Lighting*	*Heat*			
1955	0.533	0.123	0.46	0.206	1.844	16.127	19.293
1960	0.785	0.238	0.49	0.42	4.582	16.86	23.375
1965	1.158	0.462	0.54	0.91	9.068	17.34	29.498
1970	1.600	0.857	0.58	1.25	18.673	12.84	35.800
1975	2.280	1.625	0.61	1.67	37.305	nil	43.490

Year	*Rural population*				*Total Primary*	*Total Secondary*	*Total*
	Electricity (lighting only)	*Kerosene (lighting only)*	*Secondary*	*Total*			
1955	0.011	1.394	77.29	78.701	4.569	93.425	97.894
1960	0.028	2.083	80.40	82.511	8.626	97.260	105.886
1965	0.074	2.307	82.00	84.381	14.539	99.340	113.879
1970	0.198	2.572	84.75	87.520	25.730	97.590	123.320
1975	0.557	2.862	88.00	91.419	46.909	88.000	134.909

FIGURE 3

Demand for Energy in Households, 1955 to 1975

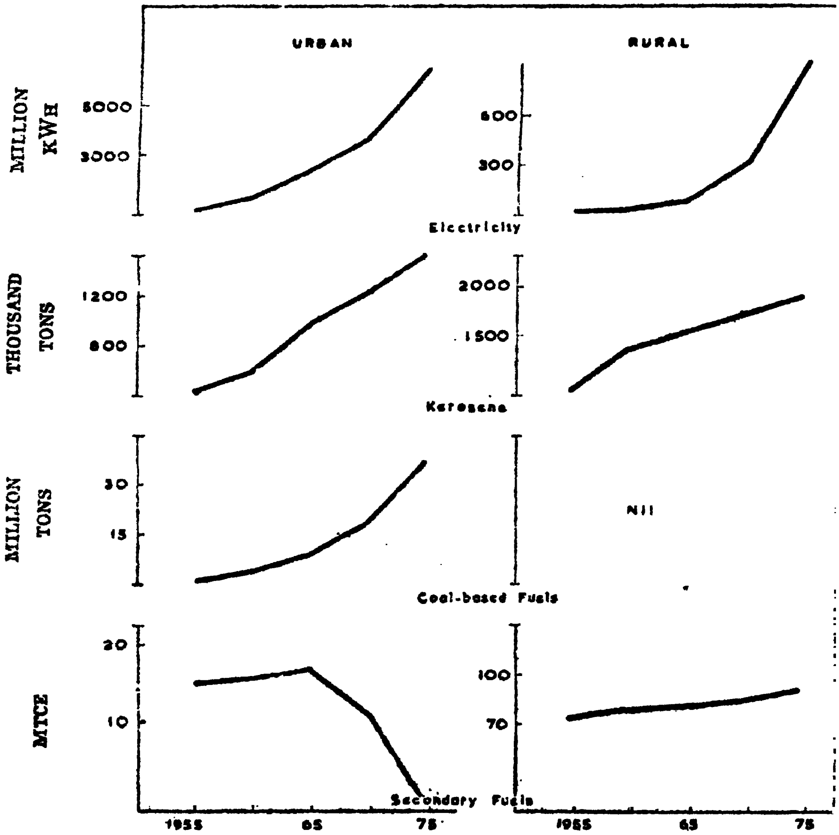
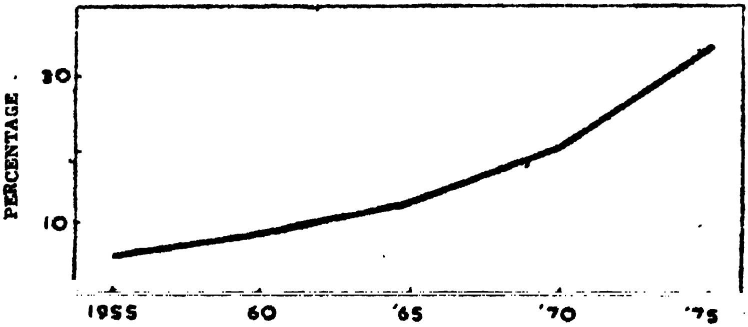


FIGURE 4

SHARE OF PRIMARY FUELS IN TOTAL DOMESTIC ENERGY, 1955 TO 1975



CHAPTER VI

ENERGY IN TRANSPORTATION

6.1 A major share of transport energy is at present taken up by railways which account for over 80 per cent of the total. This is obviously a result of the relatively slow growth of other forms of transport which between them (excluding animal transport) probably do not carry more than a very small proportion—estimated at about 8 million tons as against 140 million tons carried by the railways—of the total traffic in the country. The heavily rail-oriented transport economy is, however, expected to undergo substantial structural changes in the future, with roadways opening up the country faster than in the past and carrying progressively larger proportions of the total traffic.[60] The railways will still carry a fairly large share of the traffic, particularly of the long-distance heavy goods traffic, but its proportion will naturally decline and so will, in all probability, the proportion of its share of energy consumption. It would be interesting to examine in a general way the relationship between the rate of decline of the proportion of rail traffic (to total traffic) and the corresponding rate of fall in energy consumption, before going on to a detailed consideration of the problem.

6.2 The pattern of coal consumption on the railways has not changed much over the last few years and is roughly as shown in Table 6.2.1 for 1955-56.[61]

Roughly, therefore, about three-quarters of the consumption is accounted for by the main traffic and the rest by overhead services. The total goods traffic was 114 million tons, distributed under different heads as indicated in Table 6.2.2.

It will be seen that about 30 per cent of the rail traffic is coal of which over a third is meant for the consumption of the railways alone. Besides, railway stores account for about 9 per cent, so that the net external or non-railway traffic is about 80 per cent of the total. Now, if we distribute the overhead services' consumption over the goods and passenger traffic in the ratio of their individual consumption of coal, the unit consumption would work out at 63.6 tons of coal per 1,000 tons of goods traffic, or 450 pounds per 1,000 ton-miles. For passenger traffic, 131.5 tons of coal are required

TABLE 6.2.1

CONSUMPTION OF COAL IN RAILWAYS, 1955-56

(million tons)

Services	*Coal consumption*	*Percentage*
Passengers and mixed	3.81	30.7
Goods	5.42	44.0
Total traffic	9.23	74.7
Shunting including siding	1.31	10.6
Locos on miscellaneous services	0.23	1.8
Departmental	0.42	3.4
Water pumping stations	0.31	2.5
Electricity generating stations	0.39	3.3
Miscellaneous	0.45	3.7
Total services	3.11	25.3
Grand Total	12.34	100.0

TABLE 6.2.2

GOODS TRAFFIC ON INDIAN RAILWAYS, 1955-56

Traffic	*million tons*	*Percentage*
Coal for the public	22.3	19.6
Coal for railways	12.3	10.8
Total coal	34.6	30.4
Grains	9.0	7.9
Oilseeds	1.8	1.6
Other commodities	58.3	51.2
Railway stores	10.3	8.9
Total non-coal	79.4	69.6
Grand Total	114.0	100.0

for 1 million passenger-miles of traffic, or 295 pounds per 1,000 passenger-miles.

By road, a petrol-driven truck with a pay load of 6 tons and a load factor of ¾ will carry about 45 ton-miles of traffic per gallon of petrol, while a diesel-driven truck of the same capacity will carry about 60-65 ton-miles per gallon of diesel oil.[62] Is terms of passenger-mile, the figures would be 400 passenger-miles per gallon of petrol and 500 passenger-miles per gallon of diesel. This is equivalent to about 14,000 ton-miles and 120,000 passenger-miles per ton of petrol and 16,500 ton-miles and 130,000 passenger-miles per ton of diesel respectively. On the other hand, a ton of coal on the railways will carry about 5,000 ton-miles of goods traffic or 7,500 passenger-miles of passenger traffic. Allowing for the conversion coefficient this works out as follows:

TABLE 6.2.3

SPECIFIC CONSUMPTION OF ENERGY IN RAIL AND ROAD TRANSPORTATION

(tce)

Consumption per	*Rail (steam)*	*Road (petrol)*	*Road (diesel)*
1,000 ton-miles	0.20	0.107	0.091
10,000 passenger-miles	1.33	0.125	0.116

The reason why steam-borne rail traffic is so energy-intensive in comparison with either petrol or diesel-driven traffic is the abysmally low efficiency of steam traction, about 4 per cent.[63] *A doubling of overall efficiency (by the partial introduction of electrification* or diesel traction) would bring the goods traffic very close to conditions of energy parity but would not affect the passenger traffic parity to any appreciable extent. The table, however, makes it clear that a shift from rail traffic to road, whether petrol or diesel-driven, or from steam traction to electric or diesel traction on the railways will ultimately result in saving of energy through relatively lower energy imputs per unit of traffic carried. A 10 per cent switchover from rail to road traffic (goods) will be accompanied by a 5 per cent decline in energy consumption, and a similar shift in passenger traffic by a saving of about 9 per cent of total energy consumption. In view of the current trend *away from 'steam' rail traffic, a considerable saving in transportation energy may be expected in future.*

6.3 The railway goods traffic falls roughly in two categories: industrial, and non-industrial (that is, mainly agricultural). It was found that the industrial traffic is closely related to the index of industrial production,[64] and the agricultural traffic to the total consumption of foodgrains in the country.[65] On this basis, the following projections of the two categories of traffic have been arrived at:

TABLE 6.3.1

ESTIMATE OF GOODS TRAFFIC BY RAIL, 1955-56—1975-76

Year	Index of industrial production	(million tons)			
		Industrial goods traffic	Food consumption	Agricultural goods traffic	Total goods traffic
1955-56	122	93	81	23	116
1960-61	185	140	94	27	167
1965-66	285	212	105	30	242
1970-71	420	312	119	34	346
1975-76	610	450	134	39	489

The last column gives the total volume of goods traffic which the railways will be expected to carry if the current relationship between its capacity and the traffic generated within the economy remains unaltered over the next few decades. The railway capacity may expand faster than the rate of increase of traffic in the country in which case these figures will be improved upon; on the other hand, it may be unable to keep pace with the increasing tempo of industrial and agricultural growth in the country with the result that these figures may prove to be gross over-estimates. As a first approximation, it may be assumed that the present relationship will hold, and adjustments may be made later on when the picture of total long-distance traffic and the share of railways therein is a little clearer.

6.4 The growth of passenger traffic is rather difficult to estimate. During the First Plan, the number of passengers actually declined from 1,279 to 1,275 million, although since 1952-53, the trend would appear to be generally positive.[66] In terms of passenger-miles, there has been virtually no increase since the end of the war, and in 1955-56 the number of passenger-miles registered was less than in 1945-46. There is no doubt, however, that there is considerable pressure on rail passenger traffic and that, if the constraints were removed, it would probably register a steady growth in keeping with rising incomes and progress of urbanization. A precise relationship between the volume of passenger traffic and the various factors which influence its growth is difficult to establish, but it is assumed here that it will grow about half as fast as goods traffic:

TABLE 6.4.1

ESTIMATE OF GOODS AND PASSENGER TRAFFIC BY RAIL 1955-56—1975-76

Year	*Total goods traffic* (million tons)	*Total passenger traffic* (million passenger miles)
1955-56	116	38.7
1960-61	167	47.2
1965-66	242	57.8
1970-71	346	70.0
1975-76	489	84.5

6.5 The average lead of goods traffic has been steadily increasing from about 260 miles in 1938-39 to 322 miles in 1956-57, an increase of a little over one per cent every year. With the diversification of economy and the general higher mobility of men and materials which it implies, this average lead may be ordinarily expected to increase; however, the fact that a good many of the basic industries will be located on a decentralized basis in the future may check this trend, if not actually reverse it. If we ignore the element of decentralization, the quinquennial increase in lead would be of the order 5-6 per cent.

So far, we have not considered the effect of the fuel efficiencies on the unit energy requirements. The fuel efficiencies on Indian railways have been generally erratic, and for some types of traffic are today actually less than thirty years ago.[67] Over this thirty-year period, the efficiencies were at their lowest in 1947-48 and thereabouts, but have since been steadily increasing at a rate which has been placed at about 6.6 per cent in five years. With the growing reliance of the railways on low grade coal and for several other reasons it is doubtful where this rate of improvement in efficiencies can be sustained over an extended period without a large-scale switchover from steam to either electric or diesel traction. In any case, the current rate of improvement is roughly of the order of the quinquennial increase in average lead referred to earlier and may be assumed to counter-balance the other. Considering all these factors, it would not be unreasonable to proceed on the basis of constant lead over the next few years.

6.6 On this basis, the following estimates of energy requirements have been made:

TABLE 6.6.1

ESTIMATE OF DEMAND FOR ENERGY FOR HAULING GOODS AND PASSENGER TRAFFIC BY RAIL, 1955-56—1975-76

(mtce)

Year	*Goods traffic*	*Passenger traffic*	*Total*
1955-56	7.35	5.00	12.35
1960-61	10.60	6.12	16.72
1965-66	15.40	7.50	22.90
1970-71	21.90	9.05	30.95
1975-76	31.00	10.90	41.90

These would be the total requirements of coal if the whole of the traffic were carried by steam locomotives. However, the need to improve the overall efficiency of the transportation system and to reduce the consumption of high grade coal (in steam locomotives) will necessarily bring about a shift from steam to more efficient modes of traction. The alternatives are: electrification and diesel traction. Electrification would appear to be more suitable for Indian conditions, and as far as it implies a shift from high grade to low grade coal, a move in the right direction. Diesel traction, on the other hand, may be an economic proposition only under specific conditions of traffic, for shunting services, for instance. Moreover, its use in railway traction will be decided by the prospects of its availability in future, especially as the roadways will have greater claim on it, considering that, it is, under the present technological conditions, probably the most efficient fuel available for the purpose. It appears, therefore, that while dieselization may be resorted to in the case of certain selected traction services, it may not replace more than a small fraction of the future rail tractive capacity. Reference has been made (vide para 4.10) to a suggestion by a railway fuel expert committee to electrify at least 30 per cent of the tractive capacity by 1975-76 and dieselize another 20 per cent or so. Since about 10-12 per cent of the total energy consumption by the railways is in shunting, it is obvious that the committee is thinking in terms of extending the use of diesel beyond shunting services. The ratio of thermal efficiencies of energy use in steam locomotives and electric traction is of the order of 1 : 3, and that in steam locomotives and diesel traction about 4.5 to 22, that is, 1 : 4.9.[68] In shunting services, the overall efficiency of steam locomotives drops to about 3 per cent so that the above ratio under such conditions works out at about 1 : 7.5. Using these coefficients, and accepting the committee's recommendations, the future pattern of railway fuel requirements can be visualized as follows:[69]

TABLE 6.6.2

DEMAND FOR COAL, ELECTRICITY AND DIESEL OIL IN RAILWAYS, 1955-56—1975-76

	1955-56	1960-61	1965-66	1970-71	1975-76
(1) Total consumption by railways (mtce)	12.35	16.72	22.90	30.95	41.90
(2) Proportion of 'electric traction' energy (per cent) (allowing for efficiency)	3.30	5.00	6.80	8.40	10.00
(3) Total 'electric' energy (mtce)	0.41	0.84	1.56	2.60	4.19
(4) 'Shunting' energy (mtce) (about 10.6 per cent)	1.31	1.77	2.44	3.28	4.44
(5) Proportion of (4) converted to diesel (per cent)	..[a]	10.00	25.00	50.00	100.00
(6) Diesel required for (5) (mtce) (1 : 7.5)	..	0.025	0.08	0.22	0.59
(7) Proportion of (1) converted to diesel (per cent)	..[a] [70]	..[a]	5.00	8.00	10.00
(8) Diesel required for (7) (mtce) (1 : 4.9)	..	..	0.23	0.50	0.85
(9) Total diesel (6)+(8)	..	0.25	0.31	0.72	1.44
(10) Net coal	11.12	14.04	16.56	19.03	20.70

[a] negligible.

It will be seen that by 1975-76 about half the total railway energy requirements will be met by coal (by steam traction) and the rest by electricity and diesel. Despite the fact that about a fifth of the capacity is to be converted to diesel traction, the quantity of diesel oil required is less than a million tons by 1975-76. Whether the railways, that is, in the ultimate analysis, the national economy, will be able to put through a capital construction programme of a magnitude implied in the conversion of about 15 million tons of 'steam' to electricity and diesel traction has to be seen; it is, of course, assumed here that the railways will be able to manage it.

6.7 A basic assumption underlying the projection of railway fuel requirements has been that the current relationship between the railway capacity and the total traffic generated within the economy remains more or less unaltered over the next few decades. It is, however, quite possible that the railway capacity may increase faster than the total traffic, or slower, depending upon the nature of the traffic that is developed and the rate of growth of other modes of transport in relation to the railways. It is difficult without detailed data to estimate the share of different modes of transport in the carriage of long distance traffic. The trend of industrial and agricultural development indicates that the production of the commodities listed in Table 6.7.1 would increase from about 165 million tons in 1955-56 to about 750 million tons in 1975-76.[71]

TABLE 6.7.1

ESTIMATE OF PRODUCTION OF AGRICULTURAL, MINERAL AND INDUSTRIAL COMMODITIES IN INDIA, 1955-56—1975-76

(million tons)

Commodities	1955-56	1960-61	1965-66	1970-71	1975-76
I. Agriculture					
Foodgrains	65.0	75.0	84.0	95.0	107.0
Other agricultural products — 25 per cent of Foodgrains	16.0	19.0	21.0	24.0	27.0
Total	81.0	94.0	105.0	119.0	134.0
II. Industry					
Cement	4.3	13.0	25.0	35.0	50.0
Steel & pig iron	2.9	7.0	13.5	23.0	33.5
Salt	3.7	3.7	5.0	8.0	12.0
Fertilizers	1.0	4.0	8.0	13.0	20.0
Petroleum	2.5	4.0	11.0	16.0	22.0
	14.4	31.7	62.5	95.0	137.5
Add 25 per cent for other industrial products	3.6	7.9	15.6	23.8	34.4
Total	18.0	39.6	78.1	118.8	171.9

[Contd. opp.]

III. Minerals					
Coal	36.8	60.0	100.0[a]	200.0[a]	300.0[a]
Iron ore	4.0	12.0	20.0	35.0	50.0
Manganese ore	1.3	2.0	2.5	3.0	3.5
Limestone	8.9	13.5	17.0	24.0	31.0
Total	51.0	87.5	139.5	262.0	384.5
Total of I + II + III	150.0	221.1	322.6	499.8	689.4
Miscellaneous items not listed above — add 10 per cent	15.0	22.1	32.3	49.9	68.9
Total production	165.0	243.2	354.9	549.7	758.4

[a] It will be seen later that this is an overestimate.

Of this, between 70 and 80 per cent requires long distance haulage. In 1955-56, when almost all the long distance traffic was carried by the railways (due to restriction on long distance traffic by road upto 1956), the ratio was about 72 per cent. This may be expected to increase to about 80 per cent or so by 1975, so that the total long distance traffic will work out as follows:

TABLE 6.7.2

ESTIMATE OF LONG-DISTANCE TRAFFIC BY RAILWAYS, 1955-56—1975-76

	1955-56	1960-61	1965-66	1970-71	1975-76
Total production (million tons)	165.0	243.0	355.0	550.0	758.0
Percentage of long-distance haulage	72.0	74.0	76.0	78.0	80.0
Total long-distance haulage (million tons)	120.0	180.0	270.0	430.0	605.0

In 1955-56 total railway traffic was 116 million tons, and the balance of 4 million tons was carried by coastal shipping and inland water transport. It is estimated that the share of the latter in the next five-year plans will be 7, 11, 16 and 22 million tons at the end of 1960-61, 1965-66, 1970-71 and 1975-76, respectively.[72] The balance, which will have to be carried by road, can be obtained by deducting the railway traffic estimates given in Table 6.3.1 from the above. The share of each mode of transport will thus be:

TABLE 6.7.3

ESTIMATE OF RAIL, ROAD AND MISCELLANEOUS TRAFFIC, 1955-56—1975-76

(million tons)

	1955-56	1960-61	1965-66	1970-71	1975-76
Railways (Table 6.3.1)	116	167	242	346	489
Coastal shipping & inland water transport	4	7	11	16	22
Road	nil	6	17	68	94
Total	120	180	270	430	605

It is obvious that this approach has its limitations. Because the road traffic is obtained by deducting the railway traffic from the total, a slight error in estimating total traffic can lead to a substantial margin of error in the assessment of the road traffic balance. This margin of error diminishes as the share of road traffic in the total goes on increasing, but even in 1975-76 when it will be almost 15 per cent of the total, a 10 per cent error in the overall estimate will affect the road traffic estimate by ± 66 per cent. Another factor which effects the overall estimate (and, thus the road traffic balance) is the estimate of coal production itself which accounts for almost 50 per cent of the total traffic. It is, therefore, necessary to look into this question a little more carefully, particularly with regard to the prospects of growth of railway capacity over the next couple of decades. It is generally agreed that there has been a substantial expansion in railway capacity during the two plan periods and many sections have attained saturation level. Any intensified development hereafter will demand increase of route mileages, doubling of lines, electrification, and dieselization of saturated sections. All these developments involve heavy capital outlay, and assuming that this will be in the same proportion as the increased total expenditure during the subsequent plans, the total long distance traffic expected to be carried out by railways by 1975-76 will not increase in the same proportion of the total traffic and may be about 400 million tons.[73] This is almost 90 million tons short of the estimate given in Table 6.3.1. It is clear, therefore, that either the railways have to step up their investment in order to keep pace with the rising volume of traffic, or the excess traffic has to be passed on to other modes of transport. Taking all these factors into account, Table 6.7.3 can be re-written as Table 6.7.4.

TABLE 6.7.4

ESTIMATED GROWTH OF RAIL AND ROAD TRAFFIC, 1955-56—1975-76

(million tons)

	1955-56	1960-61	1965-66	1970-71	1975-76
Railways[a]	116	163	236	313	413
Shipping and inland water transport	4	7	11	16	22
Road	nil	10	23	71	165
Total traffic	120	180	270	400	600
Percentage of railway to total traffic	96.5	90.5	87.5	78.2	69.5
Percentage of road to total traffic	nil	5.5	8.5	17.7	27.5

[a] These figures are lower than those in Table 6.3.1 by about 10 per cent. In energy terms, the difference is not very large.

According to a Road Development Plan prepared by the Chief Engineers of State Governments, the volume of road traffic has been assessed as 12, 60, 118 and 184 million tons in 1960-61, 1965-66, 1970-71 and 1975-76 respectively. These estimates, which have been arrived at on almost exactly the the same basis as adopted above, would appear to be somewhat inconsistent, at least as far as quinquennial growth rates are concerned. A five-fold increase over 1960-65 is reduced sharply to an increase of less than 100 per cent in the following five-year period, which appears unlikely and unexplicably discordant with the generally uniform rate of growth of other modes of transport during these periods. This inconsistency is inherent in the method of estimation, as explained above. In this study, the estimates given in Table 6.7.4 have been used for energy projections, as they are relatively more consistent than other estimates and would appear to be reasonably accurate.

6.8 Besides long distance traffic, roadways have to carry the feeder as well as local (short distance) traffic. These are difficult to estimate, but assuming 100 per cent of iron ore and 80 per cent of coal to be traffic suited for railways only,[74] the remainder may be assumed to require feeder transport. Some feeder traffic is also handled by bullock carts. In 1950-51, 83,500 trucks[75] (that is, total number of trucks registered) were engaged in feeder transport, and on the basis of these actual figures, the number of trucks required in future can be estimated as given in Table 6.8.1.

TABLE 6.8.1

ESTIMATE OF TRUCKS REQUIRED FOR FEEDER TRAFFIC ON ROADS, 1950-51—1975-76

(million tons)

Year	*Estimated long distance traffic*	*Traffic not requiring feeder transport*	*Net feeder traffic*	*Number of trucks required*
1950-51	93	30	63	83,500
1955-56	120	33	87	115,000
1960-61	180	60	120	159,000
1965-66	270	100	170	226,000
1970-71	400	171	229	305,000
1975-76	600	290	310	412,000

The number of trucks required for local traffic is estimated in Table 6.8.2:

TABLE 6.8.2

ESTIMATE OF TRUCKS REQUIRED FOR LOCAL TRAFFIC ON ROADS, 1960-61—1975-76

(million tons)

Year	*Total production*	*Total long distance traffic*	*Local traffic*	*Local traffic for bullock carts*[b]	*Local traffic for trucks*	*Number of trucks*[c] *required*
1960-61	243	180	63	63	nil	nil
1965-66	355	270	85	74	11	14,600
1970-71	512[a]	400	112	78	34	45,200
1975-76	750[a]	600	150	94	56	74,200

[a] Revised in conformity with Table 6.7.4.

[b] 70 per cent of agricultural traffic (see Table 6.7.1) is expected to be handled by bullock carts.

[c] Calculated on the same basis as in Table 6.8.1.

The number of trucks required for long distance traffic can also be estimated as shown in Table 6.8.3.

TABLE 6.8.3

ESTIMATE OF TRUCKS REQUIRED FOR LONG-DISTANCE TRAFFIC ON ROADS
1960-61—1975-76

Year	*Total long distance road traffic*[a]	*Million ton-miles*[b]	*Number of trucks required*[c]
1960-61	10	3,000	21,400
1965-66	23	7,000	50,000
1970-71	71	21,000	150,000
1975-76	165	50,000	357,000

[a] From Table 6.7.4.

[b] Average lead = 300 miles (rounded figures).

[c] A 6-ton truck with a load factor of 2/3 and an average annual run of 35,000 miles handles 140,000 ton-miles of traffic per annum. This is the net number of trucks required on road (without provision for spares etc.).

Combining the figures in the last three tables, the total number of trucks required would be as follows:

TABLE 6.8.4

ESTIMATE OF TRUCKS REQUIRED FOR LONG-DISTANCE, FEEDER AND LOCAL TRAFFIC ON ROADS, 1955-56—1975-76

(thousands)

Year	*Long-distance traffic*	*Feeder traffic*	*Local traffic*	*Total*
1955-56	nil	115.0	nil	115.0
1960-61	21.4	159.0	nil	180.4
1965-66	50.0	226.0	14.6	290.6
1970-71	150.0	305.0	45.2	500.2
1975-76	357.0	412.0	74.2	843.2

It is necessary to break this down further into diesel and petrol driven trucks. In 1955-56, of the total number of 115,000 trucks, only 13,000 were diesel trucks, but the proportion has been increasing rapidly since then and there is evidence to indicate that the number may amount to 35-40 thousands by 1960-61.[76] It may be assumed that the whole of long distance traffic will be carried by diesel vehicles in future, the entire local traffic by petrol vehicles, and the feeder traffic by a combined fleet of diesel and petrol vehicles, the proportion of diesel increasing from about 10 per cent in 1955-56 to 15, 20, 25 and 30 per cent in the subsequent plan periods. On this basis, the breakdown will be as follows:

TABLE 6.8.5

ESTIMATE OF PETROL AND DIESEL TRUCKS, 1960-61—1975-76

(thousands)

Year	*Diesel trucks*	*Petrol trucks*	*Total*
1960-61	45.4	135.0	180.4
1965-66	95.0	195.6	290.6
1970-71	226.0	274.2	500.2
1975-76	480.6	362.6	843.2

6.9 Trucks account for a major share of the total petroleum consumption on the road, and the percentage is expected to increase progressively as industrial expansion gathers momentum. It is, however, necessary to make an independent estimate of the consumption by passenger cars and buses, although, owing to the general paucity of reliable data with regard to passenger traffic on roads, such an estimate can be at best an intelligent guess. Correlating the number of private motor cars and taxis with per capita income and assuming that, of the total quinquennial increase in passenger traffic, the balance not carried by railways (vide Table 6.4.1) will have to be handled by road transport, an estimate of passenger buses and motor cars can be made as follows:

TABLE 6.9.1

ESTIMATE OF PASSENGER BUSES AND MOTOR CARS, 1960-61—1975-76

(thousands)

Year	*Passenger buses*	*Motor cars & taxis*
1960-61	79	263
1965-66	115	353
1970-71	151	459
1975-76	187	593

In addition, there will be a small proportion of miscellaneous vehicles whose consumption can be accounted for by adding a small percentage to the total consumption (vide Table 6.10.4).

6.10 It is now possible to calculate the consumption of these vehicles on the assumption that a motor car (or taxi) will consume annually 250 gallons of petrol, a petrol bus 2,000 gallons, a diesel bus 2,500 gallons, a petrol truck 1,500 gallons and a diesel truck 2,500 gallons. The estimates for motor spirit are given in Table 6.10.1 and for HSD (High Speed Diesel) in Table 6.10.2:

TABLE 6.10.1

ESTIMATE OF DEMAND FOR PETROL FOR PASSENGER AND GOODS TRAFFIC ON ROADS, 1950-51—1975-76

(million gallons)

Year	*Motor cars & taxis*	*Buses*	*Trucks*	*Total*	*Total in million tons*
1950-51	39.75	66.00	123.00	228.75	0.736
1955-56	49.75	60.00	153.00	262.75	0.845
1960-61	65.75	80.00	202.00	347.75	1.120
1965-66	88.25	98.00	275.00	461.25	1.490
1970-71	114.75	106.00	386.00	606.75	1.960
1975-76	148.25	112.00	512.00	772.25	2.500

TABLE 6.10.2

ESTIMATE OF DEMAND FOR DIESEL OIL FOR PASSENGER AND GOODS TRAFFIC ON ROADS, 1950-51—1975-76

(million gallons)

Year	*Buses*	*Trucks*	*Total*	*Total in million tons*
1950-51	7.50	2.00	9.50	0.036
1955-56	32.50	26.00	58.50	0.220
1960-61	97.50	113.00	210.50	0.795
1965-66	165.00	237.50	402.50	1.520
1970-71	245.00	562.00	807.00	3.050
1975-76	327.50	1200.00	1527.50	5.780

FIGURE 5

DEMAND FOR PETROL AND DIESEL OIL TRANSPORTATION
1955-56 TO 1975-76

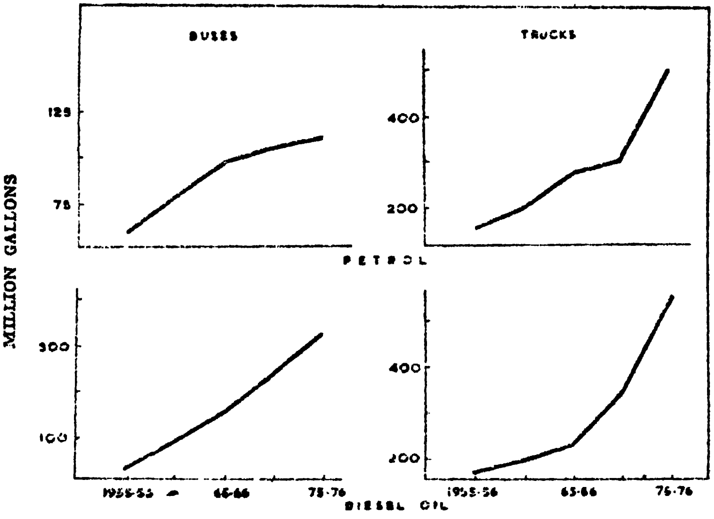
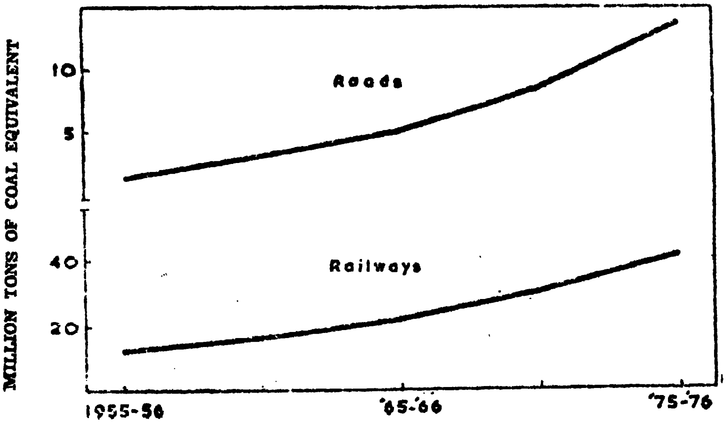


FIGURE 6

RELATIVE RATES OF GROWTH OF DEMAND FOR ENERGY IN RAIL AND ROAD TRANSPORTATION, 1955-56 TO 1975-76



The estimates given in the "Road Development Plan" are given in column 2 of Table 6.10.3. The NCAER estimates are on an average between 2 and 20 per cent lower than the RDP estimates. Considering the number of factors involved at each stage of estimation and the margin of error to which it is subject, the results can be said to be generally satisfactory. Adding 10 per cent to allow for miscellaneous consumption, the final estimates of petrol and HSD consumption (Fig. 5) would be as shown in Table 6.10.4. The relative rates of growth of energy in rail and road transportation are illustrated in Fig. 6.

TABLE 6.10.3

ESTIMATES OF DEMAND FOR PETROLEUM, 1960-61—1975-76

(million gallons)

Year	*NCAER estimate*	*RDP estimate*
1960-61	558.25	620.2
1965-66	863.75	1,036.2
1970-71	1,413.75	1,620.7
1975-76	2,299.75	2,337.7

TABLE 6.10.4

ESTIMATES OF DEMAND FOR PETROL AND DIESEL OIL, 1960-61—1975-76

(million tons)

Year	*Petrol*	*HSD*	*Total*	*Total coal*
1960-61	1.232	0.874	2.106	3.15
1965-66	1.640	1.672	3.312	4.95
1970-71	2.156	3.355	5.511	8.25
1975-76	2.750	6.358	9.108	13.60

6.11 The consumption of aviation spirit increased by two-thirds during the First Plan and the same rate of growth can be assumed for future plans.[77] In shipping, the increase was 50 per cent; the future rates of growth will probably conform to the traffic growths envisaged in Table 6.7.4. The consumption of petroleum under the two modes of traffic is estimated as given in Table 6.11.1 .

TABLE 6.11.1

ESTIMATES OF DEMAND FOR PETROLEUM IN AVIATION AND SHIPPING, 1960-61—1975-76

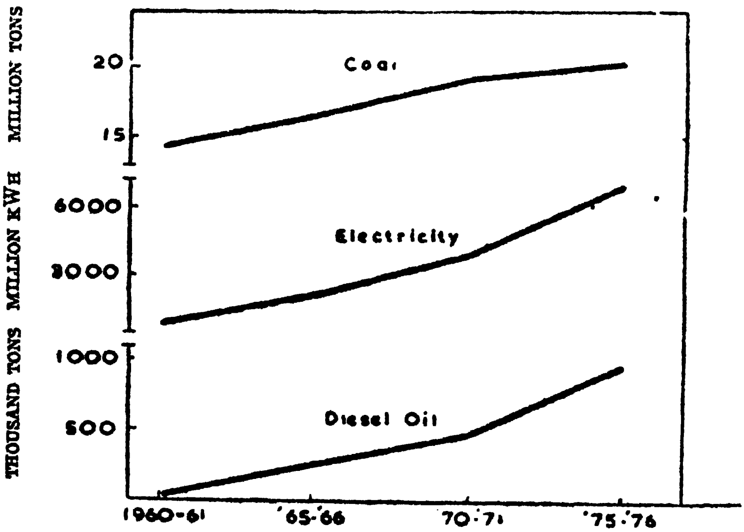
(thousand tce)

Year	*Air transport*	*Shipping*	*Total*
1960-61	280	100	380
1965-66	460	150	610
1970-71	750	225	975
1975-76	1,200	340	1,540

This completes the estimates of energy requirements of the transport sector (vide Fig. 7).

FIGURE 7

DEMAND FOR ENERGY IN RAIL TRANSPORTATION, 1955-56 TO 1975-76



CHAPTER VII

ENERGY IN INDUSTRY

7.1 An approximate idea of the energy requirements of industry were given in Table 3.9.1. This was based on a rough breakdown of the mining and manufacturing sector into heavy and light industries and certain assumptions regarding individual elasticities of energy consumption in these sub-sectors. For a more detailed estimate, it is necessary to obtain a breakup of the mining and manufacturing sectors into its various components, each of which has its distinctive pattern of energy consumption. According to the Planning Commission's estimates of sectoral outputs in the first two plans,[78] the position within the industrial sector is as follows:

TABLE 7.1.1

VALUE OF INDUSTRIAL OUTPUT, 1950-51—1960-61

(Rs. million at 1952-53 prices)

		1950-51	1955-56	1960-61
1.	Mining	800	950	1,500
2.	Factory establishments	5,900	8,400	13,800
3.	Small enterprises	7,400	8,400	10,850
4.	Construction	1,800	2,200	2,950
	Total Output	15,900	19,950	29,100

Of the total mining output, about 50-55 per cent is accounted for by coal[79] and this will be considered later under processing of energy. Of the rest, only gold and copper mining involve any energy use and they account for less than 10 per cent of the total output. Adding this to item 2, the output under factory establishments becomes Rs. 5,980, Rs. 8,495 and Rs. 13,950 million respectively. Item 3, small enterprises, is in the main a consumer of electricity, and the last item is generally non-energy consuming except for large-scale construction projects which consume mainly petroleum products. The principal energy consuming block is formed by the factory establishments and it is necessary to anticipate its growth in relation to the total industrial output as given in Table 2.4.1.

The ratio of outputs in factory establishments to small enterprises went up from 44.5 : 55.5 in 1950-51 to 50 : 50 in 1955-56 and is expected to rise further to 56 : 44 in 1960-61.[80] The percentage of construction to total industrial output has been gradually falling from 11.3 per cent in 1950-51 tto 11.0 per cent in 1955-56 and will fall further to 10.1 per cent by the end of the Second Plan. On the basis of these trends and certain other assumptions it is possible to project the individual outputs until 1975-76 as shown in Table 7.1.2.

TABLE 7.1.2

ESTIMATE OF GROWTH OF OUTPUT IN INDUSTRY, 1960-61—1975-76

(Rs. million at 1952-53 prices)

	1960-61	1965-66	1970-71	1975-76
Mining	1,500	2,500	4,400	7,500
Factory establishments	13,800	22,600	34,750	44,200
Small enterprises	10,850	13,475	15,130	16,350
Construction	2,950	3,825	4,720	5,950

7.2 Since the patterns of energy consumption within the factory establishments themselves vary as between different kinds of industries, this main manufacturing block can be further sub-divided into heavy and light industries.[44] In 1955-56, the output under 'heavy' was Rs. 1,350 million of which Rs. 260 million was accounted for by iron and steel alone. By 1960-61, the latter is expected to increase its production from 1.7 to 6 million tons of crude steel, the subsequent production targets being (provisionally) 11, 17 and 25 million tons by 1965, 1970 and 1975 respectively.[81] The non-steel heavy industries will also generally keep pace with steel expansion. On this basis, the outputs (by value) under 'heavy' manufacturing will work out as indicated in Table 7.2.1.

TABLE 7.2.1

ESTIMATE OF OUTPUT IN HEAVY INDUSTRIES

(Rs. million)

	1955-56	1960-61	1965-66	1970-71	1975-76
Iron and steel	260	920	1,530	2,600	3,820
Rest 'heavy'	1,090	3,000	5,500	9,000	13,000
Total 'heavy'	1,350	3,920	7,030	11,600	16,820
Rest 'factory'	7,050	9,880	15,570	23,150	37,28033

7.3 In 1955, the base year for these calculations, energy consumption in these groups was 3.82, 3.60, 7.42 and 10.26 mtce respectively. Without allowing for the improvement in efficiency of utilization, the energy requirements during the next two decades will be (on the basis of Table 7.2.1) as follows:

TABLE 7.3.1

ESTIMATE OF DEMAND FOR ENERGY IN INDUSTRY, 1955-56—1975-76

(mtce)

	1955-56	1960-61	1965-66	1970-71	1975-76
Iron and steel	3.82	13.60	22.50	38.2	56.2
Rest 'heavy'	3.60	9.90	18.20	29.7	42.8
Total 'heavy'	7.42	23.50	41.70	67.9	99.0
Textiles	3.95	4.94	6.17	7.7	9.6
Rest 'light'[a]	6.30	9.15	15.30	23.7	41.0
Total	17.67	37.59	63.17	99.3	149.6

[a] including small enterprises.

It is clear that the pattern of consumption will undergo a severe transformation under the impact of the growth of energy-intensive industries. While in 1955-56, the 'light' industries accounted for almost 60 per cent of the total consumption, their share will be reduced to about 35 per cent by 1975-76, almost equal to the share of the iron and steel industry in that year.

7.4 These aggregate figures of energy consumption have now to be broken down into their three components, viz. coal, electricity and petroleum. Taking electricity first, the coefficients of electrification, that is, the number of kWh per unit input of total energy, a measure of the mechanical energy used in industry as against heat and chemical energy, for the major blocks mentioned in Table 7.3.1 are given below for the years 1950-56:

TABLE 7.4.1

COEFFICIENT OF ELECTRIFICATION IN INDUSTRY, 1950-56

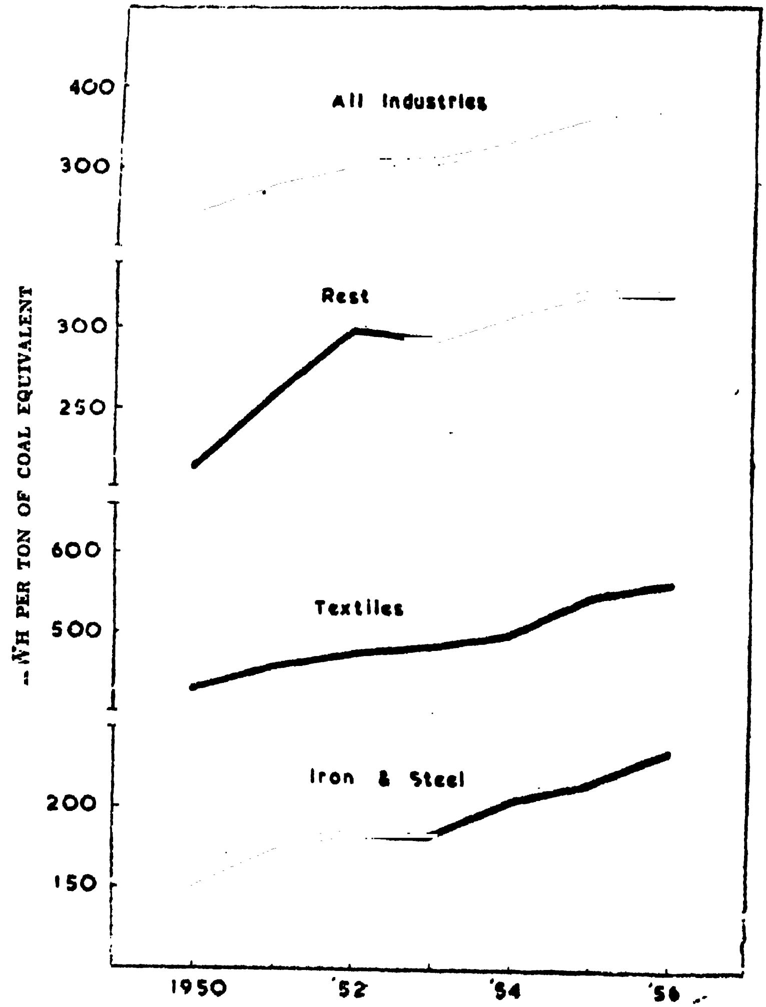
(kWh per tce)

	1950	1951	1952	1953	1954	1955	1956
Iron and steel	152	178	186	182	204	214	237
Rest 'heavy'	240	277	300	310	360	367	380
Aggregate 'heavy'	190	219	239	253	260	288	307
Textiles	428	460	476	482	500	545	564
Rest 'light'	212	260	300	295	312	327	326
Aggregate 'light'	287	334	363	357	382	409	407
Aggregate all industry	247	287	309	313	336	360	366

It will be seen (Fig. 8) that the coefficient for the industrial sector as a whole has increased by about 28 per cent in five years, the percentage increase varying from industry to industry, from about 20 per cent in iron and steel to almost 37 per cent in non-steel 'heavy' industries. The rate of increase of the coefficient of electrification is a measure of the speed of mechanization which, obviously, differs from industry to industry and is a function of, among other factors, the capacity of that industry to absorb technological innovations making for higher productive efficiencies. In countries where this process of absorption is more or less continuous, the rate of mechanization is also generally uniform and has been found to vary on an average between 2 and 4 per cent annually.[82] In low-income countries, the rate can naturally be expected to be higher (a) as they are starting from a low base, and (b) because of the higher rate of industrialization, the ratio of new to old industrial plants is increasing more rapidly than in more developed countries. It is fair to assume that this initial high rate of mechanization will, in due course, approach the normal conditions of growth in more established countries although the precise nature of this asymptotic

FIGURE 8

COEFFICIENT OF ELECTRIFICATION IN SELECTED INDUSTRIES, 1950 TO 1956



approach is a little difficult to visualize at the present moment. Taking all these factors into account, the growth of electrification coefficients can be assumed to be on the following lines:

TABLE 7.4.2

ESTIMATE OF COEFFICIENT OF ELECTRIFICATION IN INDUSTRY, 1960-75

(kWh per tce)

	1960	1965	1970	1975
Iron and steel	270	325	360	400
Rest 'heavy'	460	550	630	700
Textiles	630	720	800	880
Rest 'light'[a]	400	460	510	560

[a] including small enterprises.

7.5 Applying these coefficients to the total energy figures given in Table 7.3.1 we have:

TABLE 7.5.1

ESTIMATE OF DEMAND FOR ELECTRICITY IN INDUSTRY, 1960-75

(million kWh)

	1960	1965	1970	1975
Iron and steel	3,670	7,300	13,800	22,500
Rest 'heavy'	4,570	10,000	18,700	30,000
Total 'heavy'	8,240	17,300	32,500	52,500
Textiles	3,120	4,450	6,160	8,450
Rest 'light'[a]	3,660	7,060	12,100	23,000
Total 'light'[a]	6,780	11,510	18,260	31,450
Total	15,020	28,810	50,760	83,950
Aggregate coefficient (kWh/tce)	400	457	510	560

[1] including small enterprises.

Actually, the coefficients should have been applied to figures in Table 7.3.1 not as they stand but only after allowing for utilization efficiencies (vide para 2.6). Table 7.3.1, it will be recalled, was derived from Table 7.2.1

by applying constant energy coefficients based on the year 1955. The electrification coefficients, on the other hand, were projected mostly on the basis of historical trends which already take into account the economy in consumption consequent upon the increase in utilization efficiencies. Hence the discrepancy between these estimates and those given in Table 4.6.2, the latter having been derived on other than 'technical coefficient' method.[83] For the present, the effect of efficiency will be ignored and the estimates in tables 7.3.1 and 7.5.1 will be used as they stand. The figures can be corrected for efficiency at the final stage when all the sectoral estimates are summated to obtain overall consumption figures.

7.6 Deducting electricity (converted to coal equivalent according to Table 4.11.2), from total energy, the following non-electricity estimates are obtained:

TABLE 7.6.1

ESTIMATE OF DEMAND FOR NON-ELECTRICAL ENERGY IN INDUSTRY, 1960-75

(mtce)

	1960	1965	1970	1975
Heavy	17.40	29.70	46.8	67.5
Textiles	2.63	3.08	3.7	4.5
Light[a]	6.45	10.40	15.8	27.2
Total	26.48	43.18	66.3	99.2

[a] including small enterprises.

To separate the petroleum component from this complex it is necessary to study the present coal/petroleum patterns of consumption. In 1955, the pattern was as shown in Table 7.6.2.

TABLE 7.6.2

PETROLEUM COEFFICIENT IN INDUSTRY, 1955

(thousand tce)

	Net coal (*A*)	*Petroleum* (*B*)	B/A	$B/(A+B)$
Heavy	5,606	112	0.020	0.0197
Textiles	1,954	225	0.115	0.103
Rest 'light'	3,516	987	0.280	0.218
Total	11,076	1,324	0.119	0.106

Unlike electricity, petroleum is not associated with any specific aspect of the manufacturing process. In metal and mineral processing indutsries, and in textiles, it is, used mainly as a source of heat (in furnaces), and in the remainder of industries, also as a source of mechanical power wherever electricity is not easily available or is not competitive. At present, only about 10 per cent of the total non-electricity consumption is accounted for by oil, and whether this ratio will remain more or less stationary or change, will depend, among other factors, on the relative price movement of coal in relation to oil, and the location of future centres of industrial activity.

In terms of gross cost, oil has always been a dearer fuel than coal. According to the Census of Manufactures, the prices of coal and fuel oil (delivered at the factory) in the metal and mineral processing industries in different states in 1956 were as follows:[84]

TABLE 7.6.3

PRICE OF COAL AND FUEL OIL IN SELECTED STATES, 1956

(Rs. per ton)

State	*Coal*	*Fuel Oil*
West Bengal	21.9	224
Bombay	35.5	176
Madras	35.3	196
Punjab	32.4	336

In Bombay and Madras, both of which are situated at a considerable distance (about 700 miles) from the coal mines, the consumption of fuel oil is relatively higher[85] than in other parts of the country because of the high level of parity between the two prices. In West Bengal and the Punjab, the ratio of prices is of the order of 10 to 1 and according to available information, the proportion of oil consumption in these States is much lower than in Bombay and Madras. Although the relative price movements in the past are no reliable guide to their behaviour in the future, it is interesting to note that while the coal prices have risen through 66 per cent since 1945 and 36 per cent since 1950, the prices of fuel oil have increased about 50 per cent since 1950.[86] If these increases continue in the future, there will be no great changes in the relative consumption of the two fuels, at least as far as the price factor is concerned. If, however, the coal prices rise, as it is generally believed they will,[87] faster than the oil prices, then the consumption ratio can be legitimately expected to move in the direction of oil.[88] On the score of availability also, conditions are likely to be favourable to petroleum, at least in those areas away from mines where coal is under continuous pressure from oil. All in all, in respect of both the facts affecting the relative growth of consumption of the two substitutible fuels, oil is likely to move relatively faster than coal in the next two decades.[89]

7.7 It is difficult to quantify the effect of all these factors on consumption trends, although an attempt can be made. Assuming in the first instance, that the consumption ratio will remain the same as at present, the petroleum component of figures in Table 7.6.1 will be as under:

TABLE 7.7.1

ESTIMATE OF DEMAND FOR PETROLEUM IN INDUSTRY (CONSTANT COEFFICIENT) 1960-75

(thousand tce)

	1960	1965	1970	1975
Heavy	342	585	925	1,330
Textiles	271	317	381	464
Rest 'light'	1,400	2,260	3,580	6,160
Total	2,013	4,162	4,886	7,954

These are probably the minimum requirements of industrial petroleum. The rate of growth is of the order of about 60 per cent every five years which seems reasonable but may have to be faster. In countries with roughly the same coal/petroleum pattern as India's, the 'petroleum coefficient' has been found to be growing at a rate of between 4 to 6 per cent annually,[90] the rates varying from industry to industry, being generally high for processing industries and low for non-processing manufacturing industries. As the question of the availability of indigenous oil supplies is largely a matter of speculation,[91] the lower rates would be more realistic in this country. A quinquennial increase of 25 per cent for processing industries and textiles, and of 10 per cent for the light industries have been adopted here. On this basis, the estimates are obtained as given in Table 7.7.2.

TABLE 7.7.2

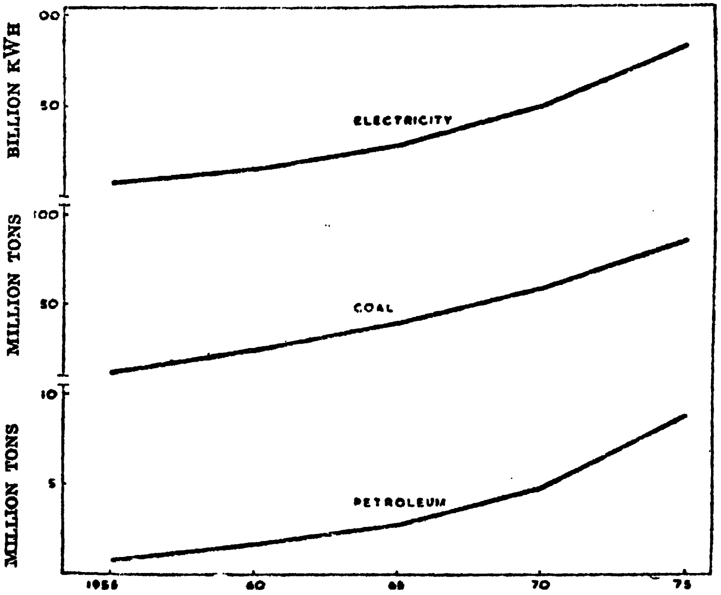
ESTIMATE OF DEMAND FOR PETROLEUM IN INDUSTRY (RISING COEFFICIENT), 1960-75

(thousand tce)

	1960	1965	1970	1975
Heavy	435	890	1,870	3,375
Textiles	342	492	740	1,120
Rest 'light'	1,560	2,780	4,620	8,750
Total	2,337	4,162	7,230	13,245

FIGURE 9

DEMAND FOR ENERGY IN INDUSTRY, 1955 TO 1975



The 'petroleum coefficient' will thus change from 10.6 per cent in 1955 to 8.8, 9.7, 10.9 and 13.3 per cent in 1960, 1965, 1970 and 1975 respectively.* Deducting these estimates from the coal-cum-petroleum figures in Table 7.6.1, we obtain the estimates of net coal requirements:

TABLE 7.7.3

ESTIMATE OF DEMAND FOR COAL IN INDUSTRY, 1960-75

(mtce)

	1960	1965	1970	1975
Heavy	16.96	28.81	44.93	64.13
Textiles	2.29	2.59	2.96	3.38
Rest 'light'	4.89	7.62	11.18	18.45
Total	24.14	39.02	59.07	85.96

This completes the estimates of industrial energy. (vide Fig. 9)

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* The drop in the coefficients in 1960 and 1968 is due to the rapid rise in coal consumption in metalliferous industries which has a relatively low 'petroleum coefficient'.

CHAPTER VIII

ENERGY IN AGRICULTURE

8.1 Energy inputs in agriculture are, roughly speaking, a function of the level of agricultural technology adopted, the levels not only varying from country to country but also according to region within the same country. Looking at the world as a whole, hand tools are characteristic of Africa, simple animal-drawn implements of the ancient cultures in Southern and Eastern Asia, and more highly developed animal-drawn and power-operated equipment of Europe, North America and the U.S.S.R.[92] Countries with a high level of agricultural technology possess, with a few exceptions, also high levels of industrial and general economic development, and vice-versa. It is, therefore, almost axiomatic that industrial expansion in India has to be accompanied by a general raising of technological levels in agriculture mainly through the adoption of intensive methods of cultivation, almost all of which lead to higher energy inputs, both directly (through mechanization) and indirectly (through the use of fertilizers etc.) The indirect inputs which flow to agriculture through other sectors have been already taken care of; the direct inputs will be dealt with here.

8.2 Between 1950-51 and 1954-55, the net area sown rose by 7 per cent (from 293 to 315 million acres) and the gross area (i.e. counting double-cropped land twice) by 8 per cent (from 326 to 352 million acres).[93] About 28 million acres are now classed as 'current fallows', another 29 million as 'fallow lands other than current fallows', and 57 million as 'culturable waste'. The present programme and long range planning do not seem to contemplate any large or rapid increase in the cultivated area. Based on the experience of the First Five Year Plan and certain programmes in the Second Plan, it would seem that something of the order of a million acres a year might be reclaimed for addition to the cultivated area on a fully economic basis, with the aid of some power equipment. This is roughly the scale of the reclamation programme that might be launched in the course of the next few years.[94]

In 1950-51 at the outset of the First Plan, about 51.5 million acres (rather more than one-sixth of the next sown acreage) were under irrigation. By the end of the Plan, 15 million acres had been added to it, the objective for the Second Plan being a further increase of 21 million acres.[95] It is not possible to say how long such rates of extension can or will be continued, in view of the fact that the ground water resources are largely unsurveyed and that increasing costs may well be encountered. It has been suggested that 100 million acres could be under irrigation by 1971. In the light of recent and current progress this seems perhaps conservative, and in any event, it is not to be viewed as an ultimate limit. Allowing for some slackening off after 1961 (on the assumption that further irrigation developments might by then encounter substantially increasing costs) we may expect 105 million acres of irrigated area by 1971, 112 million acres by 1975 and between 120-125 million by 1980.[96]

According to the Livestock Census of 1956,[97] bovines in India number roughly 200 million, divided as shown in Table 8.2.1.

TABLE 8.2.1

LIVESTOCK CENSUS OF INDIA, 1956

(millions of head)

	Total	*Cattle*	*Buffaloes*
All classes	203.5	158.6	44.9
Adult work stock	70.6	64.3	6.3
Males	68.4	62.5	5.9
Females	2.2	1.8	0.4
Breeding stock	69.5	47.6	21.9
Males	0.7	0.4	0.3
Females	68.8	47.2	21.6
Young stock etc.	63.4	46.7	16.7

Of the total adult work stock of about 70 million, only about 2 million are used in urban areas, presumably in non-agricultural activities. Applying the usual coefficients of 0.5 units per cattle and 0.9 units per buffalo,[98] we get the total animal draft power as 36.8 million units. According to the same source, 21,080 tractors were in use in India during 1956 which, reduced to draft units, give 0.13 million units. The total draft power in the country can, therefore, be taken as about 37 million units of which all but a very small portion is derived from animals. This is the present state of agriculture in India.

For the world as a whole, the total draft power was 231 million units (in 1948-49, the last year for which complete details are available), of which 199 million units were animal draft and the rest derived from power-driven machinery (mainly tractors). The growth since 1930 has been as follows:

TABLE 8.2.2

ANIMAL AND MECHANICAL DRAFT POWER IN THE WORLD, 1930-48

(million units)

	Tractors	*Draft animals*	*Total*
1930	7.7	214.2	221.9
1938-39	14.9	210.3	225.2
1948-49	31.4	199.2	230.6

It will be seen that while the total draft power has increased by just about 2 per cent every eight or ten years, the number of tractors has doubled itself during this period. According to the same source, the number of tractors has gone up from 1.3 million in 1930 to 2.5 million in 1938-39 and 5.2 million in 1948-49. The figures for some selected countries and regions are as under:

TABLE 8.2.3

NUMBER OF TRACTORS IN SELECTED COUNTRIES, 1930-48

(thousand units)

	1930	1938-39	1948-49
North America	1,020	1,597	3,700
United Kingdom	20	60	285
U.S.S.R.	72	523	500
Europe	110	205	501
Latin America	20	35	70
Oceania	32	53	101

SOURCE: *Farm Mechanization*, FAO (Rome), 1952.

In India, as Table 8.2.4 shows, the extent of modernization and mechanization is still insignificant. But the rate of mechanization is fairly rapid and should continue to be rapid in future. Of the total number of tractors in the Census returns, about 500 tractors were used in reclamation work and the rest in mechanical cultivation.[99] A tractor serves about 100 acres, so that the proportion of mechanically cultivated area to total area under irrigation works out as shown in Table 8.2.5.

TABLE 8.2.4

AGRICULTURAL IMPLEMENTS IN INDIA, 1945-56

(thousand units)

	1945	1951	1956
Wooden ploughs	27,306	31,809	36,615
Iron ploughs	481	930	1,366
Carts	8,483	9,853	10,991
Oil engines	12	82	122
Electric pumps	9	25	55
Farm tractors	5	8.5	21

TABLE 8.2.5

PROGRESS OF MECHANIZED CULTIVATION IN INDIA, 1945-55

(million acres)

	1945	1950-51	1955-56
(A) Total area under irrigation	45.00	51.50	66.50
(B) Area under mechanical cultivation	0.50	0.80	2.05
B/A per cent	1.11	1.55	3.07

If we assume the coefficient B/A to double itself every five years (as it has done between 1950-55), then the total area under mechanical cultivation will increase as shown in Table 8.2.6.

TABLE 8.2.6

ESTIMATE OF AREA UNDER MECHANICAL CULTIVATION, 1955-56—1975-76

(million acres)

	1955-56	1960-61	1965-66	1970-71	1975-76
Area under irrigation	66.5	87.5	97.5	105.0	112.0
B/A per cent	3.07	6.0	12.0	25.0	50.0
Area under mechanical cultivation	2.05	5.25	11.7	26.2	56.0

By 1975-76, therefore, the number of tractors in use will be about 560,000, which is roughly the number Russia had in 1938-39.[100] In 1930, Russia had only 72,000 tractors, the rate of increase in the intervening period having been of the order of 30 per cent annually, equivalent to a redoubling period of three years. In India, the rate will have to be much slower, about 20 per cent annually. In Great Britain, under pressure of war-time economy, the increase was almost five-fold in ten years (from 1938-39 to 1948-49).[100] If the Indian food problem is tackled as a measure of the most serious economic and political emergency (as it was done in Great Britain during the war), then the target of 560,000 tractors by 1975 may actually be an underestimate. There have been suggestions, from the most conservative quarters, that it will be necessary to provide for the production of one million tractors in ten years' time in this country at the rate of 100,000 tractors per year.[101] A figure of half a million tractors in twenty years time can, therefore, be taken as a reasonably likely target to be aimed at. On the basis of 500 gallons of consumption per year per tractor, the requirements of oil would work out as follows:

TABLE 8.2.7

ESTIMATE OF OIL CONSUMPTION BY TRACTORS, 1960-61—1975-76

(tons)

Year	*Oil*	*Coal equivalent*
1960-61	100,000	150,000
1965-66	220,000	330,000
1970-71	500,000	750,000
1975-76	1,060,00	1,590,000

An additional small number of tractors will be required for reclamation purposes. A tractor can reclaim about 1,000 acres annually, so that one thousand tractors will be required for one million acres every year. Their consumption of oil will be so small in comparison with that of farm tractors that it can be ignored or assumed to have been included in the above figures.

8.3 The number of oil engines with pumps for irrigation purposes has increased by 50 per cent between 1951 and 1956, a sharp fall from the previous seven-fold increase between 1945 and 1951. Although the 1951-56 figures cannot be taken as representative of the scale of demand for this particular type of agricultural machinery during this period, there is no doubt that with the growth of electrification in rural areas (already taken into account in projecting electricity requiremens) the demand for diesel-driven pumps may not show more than a minimal degree of increase. Assuming a 50 per cent increase in five years until 1965 and 25 per cent thereafter, the consumption will be as shown in Table 8.3.1.

TABLE 8.3.1

ESTIMATE OF OIL CONSUMPTION BY OIL ENGINES, 1956-76

Year	*Number of oil engines*	*Consumption of oil* (tons)
1956	122,000	142,000
1960-61	170,000	200,000
1965-66	250,000	300,000
1970-71	320,000	375,000
1975-76	400,000	460,000

8.4 This completes the estimates of energy requirements of all the major sectors by type of energy. The requirements of minor sectors (such as services which are not organically related to energy consumption) are largely a matter of judgment; in any case, they form a very small fraction of the total energy complement and do not really affect the overall picture as formed by the major relatively energy-intensive sectors. It should, therefore, be possible to fill in the minor gaps and complete the general framework without much difficulty. Tables III to VI have been prepared on this basis. The sectoral aggregates are summarized in Table 8.4.1 and illustrated in Fig. 10.

FIGURE 10

DEMAND FOR EFFECTIVE ENERGY IN INDUSTRY, TRANSPORTATION, HOUSEHOLDS AND SERVICES, 1955 TO 1975

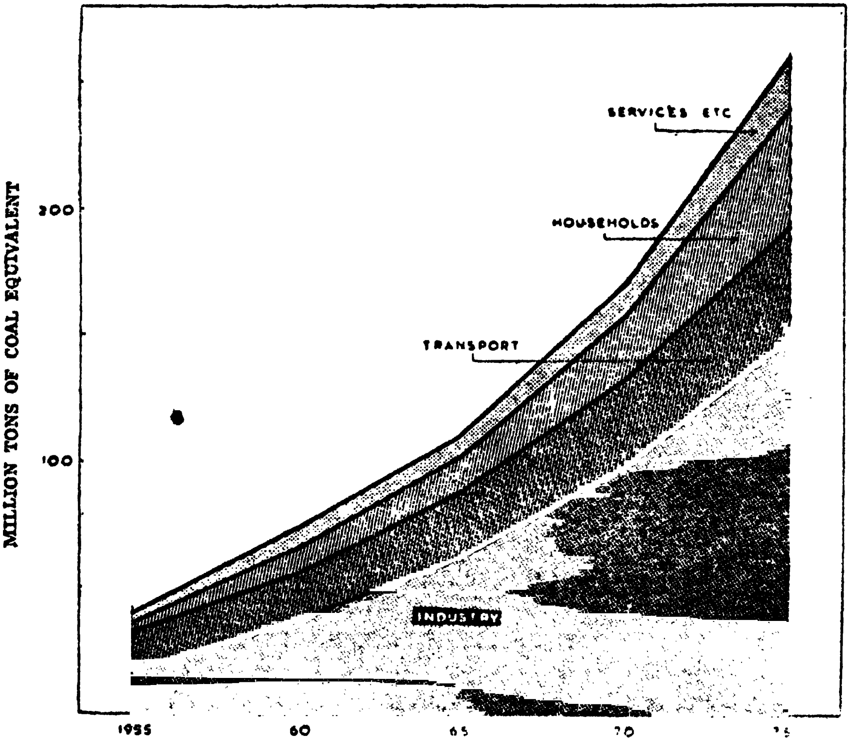


TABLE 8.4.1

ESTIMATE OF DEMAND FOR ENERGY BY SECTORS, 1960-75

(mtce)

Energy consumption	1960	1965	1970	1975
Industry	37.6	63.2	99.2	149.6
Transport[a]	19.0	25.0	33.1	44.0
Domestic				
Primary	8.6	14.5	25.7	46.9
Secondary	97.3	99.3	97.6	88.0
Services and Miscellaneous[b]	4.7	7.5	12.1	20.0
Total	167.3	209.4	267.8	348.6

[a] including transport of coal and petroleum but excluding transmission of electricity.

[b] including construction.

A comparison with the overall projections made earlier (Table 3.12.2) shows that the method by sectors yields estimates which are on the whole higher than those arrived at by the "overall" method. This was, of course, anticipated earlier (vide para 2.2) when, in assessing the relative merits of the two methods it was stated that while "in the more developed countries, there was no great difference between the two methods, in a country like India, the change in economic structure (especially the progressively greater incidence of manufacturing activity) was a major factor to be taken into account". The fact that the energy-intensive processing industries (like steel) within expanding manufacturing sector were expected to grow relatively far more rapidly could not be taken cognizance of in the "overall" method. Apart from this, the other sectoral estimates are in fair agreement with those arrived at individually and can be taken as reasonably accurate.

CHAPTER IX

CONSUMPTION BY TYPE OF ENERGY

9.1 Table 9.1.1 gives a synoptic view of effective energy requirements for 1960-75. These figures include energy consumed in transporting energy (excluding transmission of electricity) in addition to effective energy as defined in para 2.5, but excludes energy required for extracting and processing, and losses. It should also be mentioned that the figures under coal and petroleum refer only to primary consumption of these energy sources and exclude electricity derived therefrom. As such, the tables give an incomplete picture of the final pattern of consumption by type of energy (Fig. 11) but are, nonetheless, extremely useful as illustrative of the future trends in consumption. It will be seen (Table 9.1.2) that while the share of coal in the total energy will go on decreasing and that of electricity gradually increasing, the contribution of petroleum which rose to 14.0 from 11.4 per cent during 1950-55 will not undergo much change, and will remain more or less station-

TABLE 9.1.1

ESTIMATE OF DEMAND FOR EFFECTIVE ENERGY BY TYPE OF ENERGY, 1950-75

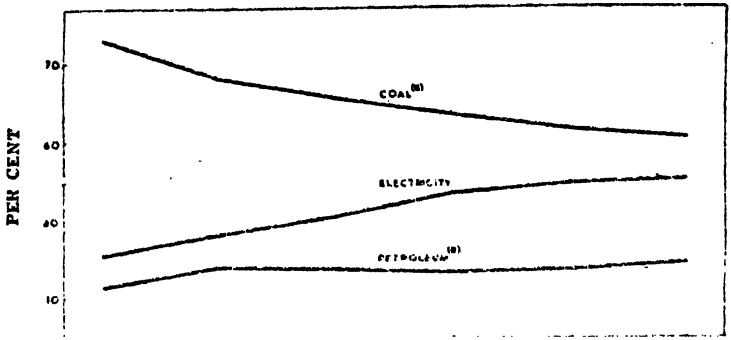
(mtce)

Year	*Coal*[a]	*Electricity*[b]	*Petroleum*[c]	*Total*
1950	23.34	4.97	3.75	32.06
1955	27.07	7.16	5.54	39.77
1960	45.81	14.44	9.69	69.95
1965	69.47	25.63	15.01	110.11
1970	104.77	41.92	23.56	170.25
1975	157.46	64.93	38.21	260.61

[a] excluding coal used in power stations.
[b] coal equivalent according to conversion coefficients in Table 4.11.2.
[c] excluding petroleum used in power stations.

FIGURE 11

SHARE OF COAL, ELECTRICITY AND PETROLEUM IN EFFECTIVE ENERGY CONSUMPTION, 1950 TO 1975.



ª mainly as heat, coal and petroleum used in electricity are excluded.

TABLE 9.1.2

PATTERN OF EFFECTIVE CONSUMPTION OF COAL, ELECTRICITY AND PETROLEUM, 1950-75

(per cent)

Year	*Coal*	*Electricity*	*Petroleum*	*Total*
1950	73.0	15.6	11.4	100.0
1955	68.0	18.0	14.0	100.0
1960	65.5	20.6	13.9	100.0
1965	63.4	23.3	13.3	100.0
1970	61.8	24.7	13.5	100.0
1975	60.5	25.0	14.5	100.0

ary at 13-14 per cent. The relatively abnormal rise in the contribution of petroleum to total energy from 1950 to 1955 was apparently due to the fact that during this period there was only a mild increase in the consumption of net coal, less than 4 million tons in five years. With the increasing orientation of the economy towards metalliferous industries from the Second Plan onwards, the pressure on coal is likely to be extremely heavy so that it would be unrealistic to expect petroleum to sustain the rate of relative increase that it attained during 1950-55. It is, therefore, not surprising to see that while the share of coal went down 7 per cent during 1950-55, the rate of decline will gradually decelerate until, by 1975, it will have come down only about 2 per cent from the 1970 level. The Indian energy economy in 1975 will be substantially a coal-based economy, and even by AD 2000 it may have as high a proportion of net coal as 55 per cent if the present trends endure.*

9.2 It is now necessary to obtain a break-up of aggregate electricity consumption by source of energy, viz. coal, hydro and oil, and add this to net coal and oil requirements to obtain gross figures of consumption. Effective electricity consumption (including transport but excluding transmission of electricity) is estimated as shown in Table 9.2.1 (vide Table 4.11.1 with corrections for industry and transport as per Tables 7.5.1 and 6.6.2).

TABLE 9.2.1

EFFECTIVE CONSUMPTION OF ELECTRICITY, 1960-75

(million kWh)

Year	*Consumption*
1960	19,530
1965	36,900
1970	64,500
1975	108,000

Between 1950 and 1955, while the total generation increased from 6,573 to 10,776 million kWh (including electricity produced in self-generating establishments), the output of diesel stations increased only slightly from 199 to 233 million kWh. The share of diesel stations was thus reduced to about 2.2 per cent from 3.0 per cent in 1950. If this trend continues, the output from diesel stations may be somewhat on the lines as given in Table 9.2.2 over the next fifteen years.

The diesel generator is used principally for small operations in remote areas, and also as a standby plant in some factories. Most of the stations are under 1,000 kW, and more than half are under 250 kW.[102] These may be thought of as temporary units, warranted in the first stage of electrifica-

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* As recently as 1946, coal provided nearly half of the fuel energy consumed in the U.S.A. (*Fortune*, November 1958.)

TABLE 9.2.2

ESTIMATED OUTPUT OF DIESEL STATIONS, 1950-75

(million kWh)

Year	*Total output (effective)*	*Proportion of diesel power* (per cent)	*Output from diesel stations*
1950	6,573	3.02	199
1955	10,776	2.20	233
1960	19,530	1.61	315
1965	36,900	1.18	437
1970	64,500	0.86	555
1975	108,000	0.63	680

tion and to be superseded by larger stations or low-voltage transmission. Although their initial unit capital costs are lower than those of coal stations, the high price of diesel (compared to coal) renders them uneconomical in the long run.[103] In the northern part of Bombay State where diesel oil is delivered by rail at a price of about Rs. 250 per ton, electric power rates to domestic consumers are as high as 75 nP. per kWh and even higher. Even in Assam, the rates are sometimes as high as one rupee per unit.[104] From the point of view of price and general economy, therefore, diesel power generation compares unfavourably with either coal or hydro power and is unlikely to make much headway in the coming decades, particularly as the power economy during these years will be geared to large-capacity stations connected through high voltage transmission grids supplying energy at 4 to 6 nP. per unit.

This question of power generation from liquid fossil fuels cannot, however, be divorced from the wider one of development of indigenous petroleum resources during the next few critical years. The overall picture of oil exploration and development in India today is one of increased activity in a number of widely separated areas—the extensive alluvial plains of the Ganga valley and the Jaisalmer desert where aero-magnetic surveys have indicated enormous thickness of sedimentary rocks, the various Siwalik structures of Kangra district in the Punjab (Jwalamukhi and the environs), the Gulf of Cambay and Kathiawar in Bombay State, the Upper Assam Valley, and some of the narrow stretches along the west and east coasts bordering the peninsula over which thin marine sediments have accumulated during the Cretaceous and Tertiary periods. The more promising areas are being thoroughly examined at present, although it is generally felt that in several of the areas the prospects of finding oil cannot be considered very promising.[105] The Oil and Natural Gas Commission has now been in existence for about three years during which period it has been able to put through an intensive programme of exploration and drilling.[106] The petroleum 'climate' in India can therefore be described as one of cautious optimism although the situation is far too uncertain at the moment for a reasonably firm appreciation of the likely future prospects of petroleum in the country.

Whatever the future prospects—and the costs of processing an extensive programme of oil exploration, about Rs. 600 per ton according to international experience,[107] should not be minimized—the immediate achievements are, by no means, a disappointment. India's crude petroleum production now amounts to about 0.4 million tons from the Digboi field, to which may be added the 2.5 million tons expected from the Assam Oil Company's discoveries in Nahorkatiya and Moran. The indigenous crude output is thus about 3 million tons, roughly half the current estimated consumption. It has been suggested that, allowing for normal depletion of presently discovered reserves, exploratory effort should be directed towards discovering additional crude oil production enough to bring the country near self-sufficiency by 1975 or so.[108] This suggestion has come both from official as well as private quarters[109] and may therefore be considered as defining the scope and direction of petroleum development in India in the coming years. Should oil be actually struck and its cost come down to a reasonable level, the shift towards petroleum may be far greater than assumed in this study and may push up the total demand for petroleum products in the country to twice or even three times the estimates made here.[109]

Against this rather hopeful background of future prospects for oil in the country, it is quite possible that the output from diesel stations may be higher than that derrived in Table 9.2.2 Diesel units of 2,000–5,000 kW would be useful during the next couple of decades to furnish power for mines and for village and agricultural use (deep well irrigation etc). Although the unit cost of power from such small 'package' stations may be generally higher than that from coal-stations, the low requirements of initial capital and the saving in transmission costs may swing the balance in favour of diesel, particularly in areas away from the collieries. Taking all these factors into account, it is reasonable to assume that the growth of diesel power output will be as indicated below:

TABLE 9.2.3

ESTIMATE OF DEMAND FOR OIL BY DIESEL STATIONS, 1960-75

Year	*Estimated output* (million kWh)	*Diesel required* (mtce)
1960	315	0.145
1965	650	0.286
1970	1,000	0.400
1975	1,500	0.540

In addition to diesel oil, there are three other petroleum fuels, viz. natural gas, refinery gases and heavy distillates, which can be considered for production of electricity. The Cambay and Jwalamukhi regions are situated away from collieries and if the prospects of natural gas in these areas prove commercially feasible, they would provide ideal locations for power stations using this gas. It is, however, doubtful whether the cost of power would be comparable to that from coal-based stations except in an integrated chemical-cum-power production project on the lines of the lignite project at Neyveli[110] and the proposed multi-purpose scheme to utilize the Nahorkatiya gases in Assam.[111] Unconfirmed reports indicate that the cost of power for private use, that is, for use outside the projects would be in the region of 15 nP per kWh,[111] roughly three times the unit cost in medium-size coal-based stations. It is quite possible, however, that the costs in Cambay and Jwalamukhi areas may be much lower than in Assam.

Fuel oil and refinery gases are clearly an additional source of energy for thermal generation in areas where coal is expensive and refineries are close by. The first two refineries in the public sector will be located within or in the vicinity of the coal belt;[112] if oil is struck at Jwalamukhi or Cambay, the subsequent refineries may be located on the West Coast, in the North or in the South (to meet the demand for refined petroleum products in these regions) that is, away from collieries and, in certain cases, in areas with negligible or insubstantial hydro power potential. Such conditions, however, are likely to be more favourable to nuclear power than conventional generation based on fuel oil or refinery gases. The prospects for a substantial petroleum-based electricity programme would, therefore, appear to be rather dim. We may add a percentage to diesel oil figures in Table 9.2.3 to include a likely demand for additional petroleum sources for power generation.

TABLE 9.2.4

ESTIMATED OUTPUT OF ELECTRICITY FROM PETROLEUM FUELS, 1960-75

(mtce)

Year	*Diesel oil*	*Fuel oil, natural gas & refinery gases*	*Total*	*Million kWh*
1960	0.145	..	0.145	315
1965	0.286	0.100	0.386	880
1970	0.400	0.150	0.550	1,380
1975	0.540	0.250	0.790	2,200

9.3 The rest of the requirements will have to be met from coal-based thermal stations, hydro electricity and possibly, nuclear power. Before going into the question of relative economics of these three types of generation, it might be useful to examine the resources position of each of them in order to establish the limiting boundaries to which the individual energies might be subject. We shall take up the conventional sources first and then go on to nuclear energy.

The known reserves of coal in India are at least 120,000 million tons.[112] During the past few years, intensive exploration in areas like Raniganj, Jharia, Bokaro, North Karanpura, South Karanpura, Madhya Pradesh and Godavari coalfields has shown great reserves of coal which had not been known before. According to the Director of Fuel Research Institute, Dhanbad, "it is almost true to say that with every borehole we sink, new reserves of coal are being unearthed".[113] There are vast tracts in M.P., Orissa and Bihar which are yet unexplored, and it is possible that large reserves of coal underlie the areas of Deccan trap in Peninsular India.

However, although the total reserves of coal may be large, they appear to be fairly localized in Bengal, Bihar, Madhya Pradesh, Orissa and Andhra areas, and much of the reserves are of inferior quality. On the other hand, it is quite possible that future discoveries may alter this picture to a certain extent. There are reports of coal deposits in Chanda,[114] Bombay State, which, if true, will cut down the distance of coal haulage to the West Coast by almost 50 per cent. The general pattern, however, is one of localized geographical occurrences and it would be safe to assume that it will continue to be so for sometime to come. On the other hand, from the point of view of quantity alone, it can be safely assumed that there are enough reserves in the country to sustain a programme of coal-based thermal generation for years to come even if the entire output of electricity were to be produced from coal. The resources of coal, therefore, can be considered ample and need not provide a limiting factor in the growth of thermal generation until 1975.

9.4 The utilizable hydro potential of the entire country has been roughly assessed at 184,000 million kWh.[115] Since, by 1975, the aggregate demand for power is estimated around 130,000 million kWh (including transmission and other losses), it is clear that the utilizable hydro potential is, in theory, sufficiently large to meet the entire demand likely to arise by that time. From the point of view of available resources, therefore, both hydro and coal resources can be considered sufficiently large to sustain singly a programme of generation of about 130,000 million kWh annually by 1975. It is reasonable to conclude that the potential resources of conventional fuels are adequate for the country's growing needs until 1975 (and, possibly, for a long period thereafter) and that, on the score of resources at least, there is no need to resort to nuclear energy during this period.

9.5 The next aspect to be considered is the question of costs. This has always been a subject of controversy among power economists, and with the advent of atomic energy in the field, the argument has become more complex than ever. The broad facts of power situation in India can be stated as follows:

(1) The quality of coals occurring in most of the areas outside Bengal (excepting the coking coals of Bihar) is largely of inferior variety, high in ash content, and in most parts, high in moisture, and of non-coking quality. With suitable plant design, they can be most profitably utilized for the generation of power.

(2) The major limitation on the availability of coal is transport. In southern and western India, freight and handling costs exceed the pithead price considerably.[116] The capital cost of expanding capacity to supply fuel for a growing power system is about Rs. 100 or more per kW of electric plant added.[117] It is more economic to transmit electricity than transport high-ash coal by rail.[118]

(3) The inferior quality of coals and restriction in geographical occurrence imply that stations must be of central type and of large capacities in

order that specialized equipment can be used for obtaining high thermal efficiencies. The future pattern of thermal power generation is, therefore, likely to consist of central power stations of large capacities inter-connected by high voltage transmission grids for distribution of power over wide areas.

(4) Of the country's total potential of about 35 million kW hydro power, roughly 14.4 million kW are in the western, southern and central areas. The hydro resources are frequently present where coal resources are deficient or relatively expensive.

(5) The hydro-electric resources are so distributed that they form concentrations of hydro power, each major concentration being separated from the others by several hundreds of miles.[119] Spheres of influence formed by these major concentrations of power should afford an ideal natural basis for regional power development.

(6) The capital costs of thermal stations are about Rs. 1,000 per kW installed, but it has been suggested that the real cost may be nearer Rs. 1,250 per kW of *effective* capacity if the reserve capacity etc. is taken into account.[120] To this has to be added about Rs. 175 per kW to allow for the capital costs required for mining the necessary quantity of coal, and Rs. 100 per kW for transporting it over an average length of haul. The *real* capital cost of thermal stations may, therefore, be near Rs. 1,400-1,500 per kW of *effective* capacity.

(7) The capital costs of hydro schemes are determined largely by topographical and hydrological considerations and vary a great deal from one site to another. The range of costs for single-purpose power projects is from Rs. 550 at Sharavati (Mysore) to Rs. 1,545 at Rihand (U.P.).[121] In multi-purpose projects, the costs are generally higher but so are the benefits.

(8) Indications of future economic trends show that in general, capital costs of future schemes would tend to the lower limits of the prevailing range of costs of the single-purpose power projects.[122] The unit cost of power from hydro stations has a range of 1.4–3.0 nP. (depending on unit capital costs and load factor) while that from pithead thermal stations is between 2.85–3.30 nP. with coal price at about Rs. 22 per ton.[123] Large-sized thermal stations with units of 100-150 MW may lead to lower unit capital costs but these may be counter-balanced by higher running costs due to rising prices of coal. It is, therefore, reasonable to assume that, in future, while the capital costs of large-sized thermal and hydro stations may not differ very much and may actually be lower for hydro stations, the level of unit costs of thermal power will certainly be much higher than that of hydro-electricity.

It should be clear from this relative assessment of the two types of generation that while, in the short run, thermal power may have a temporary advantage over hydro power, the balance is likely to swing in favour of the latter in the near future. It is, therefore, reasonable to assume that in the years to come, the growth of hydro power is likely to be more rapid than that of thermal power, the precise magnitude of the number of factors including the location of industries, and the quality of power planning. Planning, in fact, is the crux of the problem and has to be visualized and executed on a national scale rather than on the basis of state boundaries which, in any case, were not drawn up with reference to self-sufficiency in natural resources. It is assumed here that the future power programmes will be conceived and planned with a national perspective in view and not merely by aggregating individual state programmes drawn up without relation to regional resources and inter-state requirements.

9.6 We have seen earlier that the resources of conventional fuels in India are sufficiently large to sustain a programme of electrification well after 1975. On the score of costs, however, nuclear power may offer a competitive alternative to conventional thermal generation particularly in areas away from the collieries. The economics of nuclear power are far more complex than those of conventional power but certain broad conclusions follow automatically from several studies made in this country and abroad by official and unofficial organizations including the NCAER.[124]

(1) The total investment required, including the investment in mines, processing plants, transport facilities and power stations, is about Rs. 1,500/kW per coal power and Rs. 2,425-2,575/kW for nuclear power. The capital costs of nuclear power are thus higher than even those of hydro installations. The cost per kWh of nuclear power would be practically the same as coal power at places remote from the coalfields, but almost double that of hydro power.

(2) Although nuclear power compares unfavourably with coal power at present (with regard to both capital as well as unit costs), it might be competitive in about a decade, that is, by 1970 or so, when coal power costs are expected to go up and nuclear costs come down. According to the Atomic Energy Commission, the total capital investment inventory in the third generation nuclear stations will be about Rs. 1,400/kW[125] (lower than the corresponding investment in coal power) and cost of power about 2.6 nP/kWh.

Despite the fact that some of the figures of the Atomic Energy Commission have been questioned, there is no doubt that 'threshold' conditions for

106158

the entry of nuclear power are slowly taking shape in some selected regions remote from coalfields such as Madras in the south and some parts of Kathiawar in the west. The essential point, according to the Commission, is that

> "if India is to benefit from the advantage of nuclear power 10 to 15 years hence, and be in a position to utilise further the technical developments which may be expected by then, an investment in a million kilowatts of nuclear power has to be made within the next seven years. This investment will make it possible to plan a subsequent expansion of the electrical generating capacity of the country if so desired, with a minimum doubling time of five years, for practically an unlimited period, long beyond the day when the hydro and coal reserves will have been harnessed to the maximum possible extent."[126]

On the most optimistic assumptions, the contribution of nuclear power is unlikely to be more than a small fraction of the total by 1975. A station with a capacity of 250 MW is expected to be in operation by 1965 which will produce about 3 per cent of total requirements of electricity in that year. Assuming 6 and 9 per cent for 1970 and 1975 respectively, the growth of nuclear power would be as follows:

TABLE 9.6.1

ESTIMATED OUTPUT FROM NUCLEAR STATIONS, 1960-75

Year	*Net requirements* (million kWh)	*Percentage of nuclear power*	*Total nuclear power* (million kWh)
1960	19,215	nil	nil
1965	36,020	3	1,080
1970	63,120	6	3,790
1975	105,800	9	9,520

9.7 The rest of the demand will be met by coal and hydro power. The ratio of hydro: steam generation which stood at 1 : 1.7 in 1955 is expected to be about 1 : 1 in 1960.[127] Assuming that hydro will grow relatively more rapidly than steam generation in the coming years (although perhaps not as rapidly as during the Second Plan) the breakdown as between coal and hydro will be as shown in Table 9.7.1.

FIGURE 12

OUTPUT OF ELECTRICITY BY SOURCE OF GENERATION, 1955 TO 1975

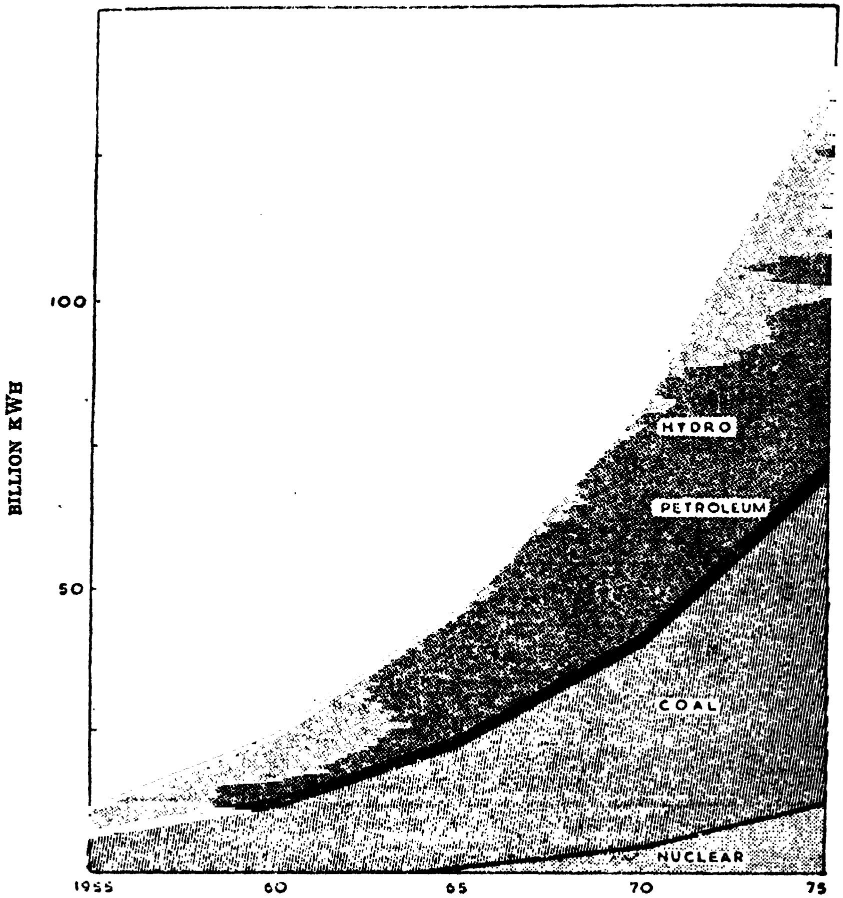


TABLE 9.7.1

ESTIMATES OF OUTPUT FROM STEAM AND HYDRO STATIONS, 1960-75

(million kWh)

Year	*Net demand (steam and hydro)*	*Ratio of steam: hydro*	*Steam*	*Hydro*
1960	19,215	1 : 1	9,607	9,607
1965	34,940	1 : 1.1	16,700	18,240
1970	59,330	1 : 1.15	27,600	31,730
1975	96,280	1 : 1.2	43,700	52,580

9.8 These figures do not include energy used in transmission. Allowing for transmission losses, the pattern of generation (Fig. 12) up to and excluding energy used in processing will be as shown in Table 9.8.1.

TABLE 9.8.1

PATTERN OF GENERATION FROM STEAM, HYDRO, PETROLEUM AND NUCLEAR STATIONS, 1960-75

(million kWh)

Year	*Steam*	*Hydro*	*Oil*	*Nuclear*	*Total*
1960	10,600	11,000	340	nil	21,940
1965	18,600	21,100	950	1,250	41,900
1970	30,800	37,500	1,490	4,500	74,290
1975	49,300	63,000	2,380	11,400	126,080

Converted to coal equivalent, the table will read as follows:

TABLE 9.8.2

PATTERN OF GENERATION (mtce) FROM STEAM, HYDRO, PETROLEUM AND NUCLEAR STATIONS, 1960-75

(thousand tce)

Year	*Steam*	*Hydro*	*Oil*	*Nuclear*	*Total*
1960	7,850	8,150	145	nil	16,145
1965	12,900	14,600	386	870	28,756
1970	20,000	24,400	550	2,920	47,870
1975	29,600	38,000	790	6,800	75,190

We have to add to this the energy requirements for extraction and processing (in collieries, power stations and refineries) and energy lost in miscellaneous conversion processes such as coke ovens etc. These losses, which can be considerable, can only be guessed at present, depending as they do on the types of processes employed in conversion. It might, however, be mentioned that as far as petroleum is concerned, it is assumed that the refining capacity in the country will rise to 10, 20 and 30 million tons of crude throughput in 1965, 1970 and 1975, respectively, from the current level of about 5 million tons. It is also assumed that the supply of indigenous crude oil will increase to 6, 12, and 24 million tons by 1965, 1970 and 1975 from about 3 million tons in 1960. Petroleum is, by far, the most capricious of fuels, and these figures may be subject to a considerable degree of revision in future if the current plans and programmes deflect substantially from the projected targets.

9.9 Final results, giving gross requirements of the three types of energy, are tabulated below:

TABLE 9.9.1

ESTIMATE OF GROSS DEMAND FOR COAL, 1960-75
(million tons)

Year	*Effective consumption*	*Electric generation*	*Extraction & conversion*[a]	*Gross consumption*
1960	45.81	8.80	7.79	62.40
1965	69.47	14.80	12.86	97.13
1970	104.77	23.20	21.80	149.77
1975	157.46	34.60	45.40	227.46

[1] Extraction losses, 6, 5.8, 5.65 and 5.5 per cent of net extraction; conversion losses, 33 per cent in soft coke plants and 20 per cent in hard coke plants.

TABLE 9.9.2

ESTIMATE OF GROSS DEMAND FOR PETROLEUM, 1960-75
(million tons)

Year	*Effective consumption*	*Electric generation*	*Extraction & losses*[a]	*Gross consumption*
1960	6.46	0.10	0.53	7.09
1965	10.01	0.27	1.05	11.33
1970	15.70	0.38	2.10	18.18
1975	25.50	0.55	3.45	29.50

[a] Extraction, 5 per cent of indigenous crude; Fuel, 5 per cent; and losses, 2.5 per cent of crude refined.

TABLE 9.9.3

ESTIMATE OF GROSS DEMAND FOR ELECTRICITY BY SOURCE, 1960-75

(billion kWh)

Year	*Steam*	*Hydro*	*Oil*	*Nuclear*	*Total*
1960	11.91	11.65	0.36	..	23.92
1965	21.16	22.38	1.00	1.37	45.91
1970	35.59	39.85	1.57	4.95	81.96
1975	57.68	67.06	2.51	12.54	139.79

TABLE 9.9.4

ESTIMATE OF INSTALLED CAPACITIES OF STEAM, HYDRO, PETROLEUM AND NUCLEAR POWER STATIONS, 1960-75

(million kW)

Year	*Steam*[a]	*Hydro*[b]	*Oil*[c]	*Nuclear*[d]	*Total*
1960	3.72	2.92	0.30	..	6.94
1965	6.40	5.60	0.50	0.25	12.75
1970	10.46	10.00	0.78	0.82	22.06
1975	16.48	16.76	1.26	1.92	36.42

[a] kWh/kW: 3,200 (in 1960), 3,300 (1965), 3,400 (1975) and 3,500 (1975).

[b] 4,000 kWh/kW.

[c] 1,200 kWh/kW in 1960 and 2,000 thereafter.

[d] 5,500 kWh/kW (in 1965), 6,000 (1970) and 6,500 (1975).

9.10 Table 9.10.1 gives the patterns of consumption, 1950-75 of both primary and secondary energies. It will be seen that while the average rate of increase of total energy will be of the order of 5 per cent per annum, that of primary energy will be about 10 per cent. During the Second and Third Plans the rate of growth is expected to be higher at about 16 and 12 per cent respectively, mainly because of the low base from which the energy economy is starting and also because of the relatively heavy investment in energy-intensive capital goods industries during these two plans. During the Fourth and Fifth Plans, the economy will have been geared to a medium pace of development as far as energy-intensive industries are con-

FIGURE 13

PERCENTAGE CONTRIBUTION OF SECONDARY TO TOTAL ENERGY, 1950 TO 1975

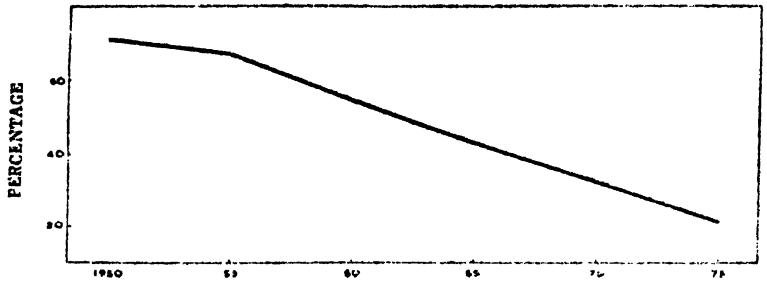


FIGURE 14

SHARE OF COAL, HYDRO-ELECTRICITY, PETROLEUM AND NUCLEAR POWER IN GROSS ENERGY CONSUMPTION, 1950 TO 1975

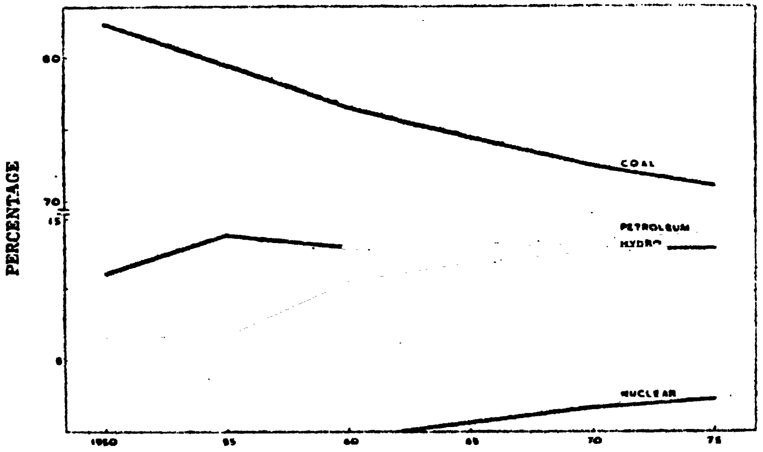


TABLE 9.10.1

PATTERN OF GROSS DEMAND FOR ENERGY BY SOURCE, 1950-75

(mtce)

Year	*Coal*	*Hydro*	*Petroleum*	*Nuclear*	*Total primary*	*Secondary*	*Total energy*
1950	29.94	2.40	4.02	..	36.36	88.20	124.56
1955	35.63	3.05	6.16	..	44.84	93.73	138.57
1960	62.40	8.65	10.63	..	81.68	97.26	178.94
1965	97.13	15.50	16.99	0.95	130.57	99.34	229.91
1970	149.77	26.00	27.29	3.22	206.28	97.59	303.87
1975	227.36	40.20	44.21	7.52	319.29	88.00	407.29

cerned and the rate will have come down to about 10 per cent. This might level off to 7-8 per cent by the end of this century.[128]

A comparison between this final pattern and the rough working framework prepared earlier (Table 3.12.2) will show that the final results are about 10 per cent higher than the previous rough calculations. The general pattern of growth, however, shows roughly the same degree of consistency as before, in terms of inter-sectoral balances as well as with respect to aggregate quantities. The results, therefore, can be considered as reasonably accurate and in line with the general trends of energy growth in other countries with similar development characteristics. (vide Fig. 13)

9.11 In percentage terms (Fig. 14), the share of coal is expected to fall to about 71 from 82.4 per cent in 1950 and 79.5 per cent in 1955. This is, of

TABLE 9.11.1

PERCENTAGE DISTRIBUTION OF GROSS ENERGY CONSUMPTION BY SOURCE, 1950-75

Year	*Coal*	*Hydro*	*Petroleum*	*Nuclear*	*Total*
1950	82.4	6.6	11.0	..	100.0
1955	79.5	6.8	13.7	..	100.0
1960	76.5	10.6	12.9	..	100.0
1965	74.5	11.9	13.0	0.6	100.0
1970	72.5	12.6	13.2	1.7	100.0
1975	71.2	12.6	13.9	2.3	100.0

course, *in accord with the general worldwide trend against coal that has been* in evidence since the beginning of the Second World War. A characteristic aspect of the changing energy patterns in India, however, is that the fall in the coal component is being taken up largely by hydro power instead of petroleum. Actually, the share of petroleum would appear to be, contrary to general impression, more or less steady at about 13-14 per cent. Its sharp rise from 11 to 13.7 per cent during the five-year period 1950-55 can probably be explained by the fact that during this period both hydro and coal had, on account of certain difficulties, registered only a slight rise of about 25-30 per cent. Coal and hydro power can be described as slow-maturing energies: it takes anything between 8 and 10 years for a coalfield to deliver its projected output and for a major hydro project to take shape and produce power. It is during the Second Five Year Plan that a substantial effort is being directed towards coal and hydro power expansion in order to keep pace with the growth of metalliferous and other energy-intensive industries planned for during this period. Since the main emphasis during the next few plans will also be on the development of such capital goods industries, it would not be unreasonable to assume that the energy pattern would continue to remain heavily coal and hydro-oriented. The growth of the Soviet coal is a case in point: The percentage of coal in the Soviet energy output[129] has remained almost stationary at about 60 per cent ever since their first Gosplan. The proportion of coal was actually higher in 1955 (64.8 per cent) than in 1927-28 (62.3 per cent), and the proportion of petroleum fuels in 1958 (32 per cent) was lower than that in 1927-28 (35.2 per cent) or even in 1913 (32.8 per cent). Since 1950, however, there has been a noticeable shift away from coal—the proportion was reduced to 59.8 per cent in 1958 from 73.2 per cent in 1950—more or less following the general trend towards diversification of their industrial complex. Another point of interest is that Soviet Russia reached between 1949 and 1950 a level of crude steel production[130] expected to be attained by India by the end of the Fifth Plan. The Soviet coal production in 1949-50 was 250 million tons, slightly higher than India's requirements (according to this study) of about 230 million tons in 1975.

9.12 The fact that the current coal output is lagging need not necessarily mean that the demand projections are over-estimates. The projections subsumed a certain rate of economic growth which, for a number of reasons, has not obviously been forthcoming. The index of industrial production was expected, according to the plan, to reach 185 by the end of 1960. In 1958, the index stood at 139, and it might reach 168 by 1960. The lag, therefore, is of the order of 10 per cent which would make the likely demand in 1960 about 56 million tons. Actually, it may be at least 2 to 3 million tons less if the steel plants, which account for a considerable slice of coal consumption, fail to attain their production schedules. These are difficulties of a temporary nature and there is no reason to believe that they would seriously affect the long-term demand projections. Short-term fluctuations can always be superimposed on the long-term growth pattern for obtaining a measure of short term deviations induced by them so long as the basic framework of assumptions governing long-term aspects of economic growth remain fundamentally unaltered.

CHAPTER X

SUMMARY AND CONCLUSIONS

10.1 Although this study has generally limited itself to the question of demand, the problem of resources, both physical and financial, from which the demand has to be met and its economic implications have been considered wherever possible. These questions are important in themselves and deserve a closer look than is possible in a specific study of this nature. The adequacy of resources is already subsumed in the hypothesis regarding the rate and pattern of economic growth during 1955-75 (vide para 2.3) which forms the basis of these projections. Energy is after all a part of the general infra-structure necessary for economic development: its own growth conditions and is, in turn, conditioned by the latter. The question of resources for energy development is thus tied up with the general problem of creating and processing resources for the entire economy and cannot really be isolated from it. The assumption is that such resources as are necessary to put through a programme of energy development outlined in this study will be available as and when called for, out of the aggregate resources required for overall economic development. This assumption is implicit in the very basis of these projections. The problem of physical resources is slightly different but this has already been taken into account at appropriate stages in this study.

10.2 It may be pertinent at this stage to ask whether the final results given in Table 9.10.1 constitute a singular solution to the problem as posed at the beginning of this study. In other words, how and to what extent would the actual requirements be expected to deviate from the pattern arrived at here? The factors that might affect the ultimate requirements may be roughly divided into (a) fatcors involving official policy consideration and (b) those influencing inter-energy substitutions. To take an instance: the question of replacement of non-commercial domestic fuels by primary energy may be theoretically tackled in as many ways as the number of primary fuels available for replacement. It may be possible to supply the households with coal or soft coke, or with such petroleum-based products as kerosene, bottled gas (LPG) and wax (for lighting). The actual pattern, as it may emerge in future, however, is rather difficult to predict, for it is likely to be decided, at least in the initial stages, by considerations not limited to purely economic. The application of economic criteria in such situations can, therefore, be largely a matter of guess and may lead to divergent results, not only because the energy requirements would be different but also because a different energy mix would yield different results (on account of varying efficiencies of utilization). In deriving the total requirements of coal, for instance, it has been assumed that the whole of the secondary energy complement in urban households would be replaced by coal (through coal-based fuels) by 1975. Although there is a good basis for this assumption, a failure to reach the replacement target would lead to a shortfall in the actual requirements of coal. This might happen despite the fulfilment of other economic targets, i.e. targets in which energy is used as a factor in production and not as a consumer product as in household consumption. The household component of total energy consumption is relatively unaffected (at least during the initial stages) by economic growth which may take place without a substantial change in the pattern of household energy consumption. In such a situation, the replacement is generally a result of deliberate policy decisions which may be only indirectly influenced by economic considerations. In as much as these policy considerations fall outside the legitimate domain of economic forecasting, they cannot be easily predicted. However, since the decisions cannot be taken without reference to the planning authorities concerned with energy development, it should be possible to introduce suitable corrections at appropriate stages of planning, as and when necessary. The projections are a function of a number of variables some of which can be only dimly visualized at present; as soon as they can be ascertained with a greater and more dependable degree of precision, they should be introduced into the main framework where provision has been made for them. These limitations apart, the findings of this study are fairly straightforward and are briefly summarized here.

10.3 *Energy and National Economy.* Energy is an essential overhead of economic growth. A tentative hypothesis on the behavior of total energy consumption in relation to economic activity can be formulated on the basis of historical trends and international comparisons. In the initial stages of development, consumption of energy generally grows at a slower rate than GNP, and, therefore, unit consumption (i.e. consumption per unit GNP) declines with time. Later, at intermediate levels of development—when there are marked changes in the structure of production, mainly consisting in the greater expansion of industry and other activities where energy inputs are proportionately higher and in a more intense growth of domestic consumption—supply requirements will increase at least as rapidly as GNP. Finally, when a high degree of development is reached and the various production sectors acquire a more stable structure, unit consumption will again decline, this time owing to the possibility of improved efficiency in the use of energy and to a partial saturation of residential demand. India is at the second (*i.e.* intermediate) stage of development when the supply requirements will increase at least as rapidly as GNP if not more. Over the past few years, the income elasticity of total energy consumption was about 0.6, while that of primary energy was about 1.6.

The energy consumption function can be written as $E = E_p + E_c$, where E is total energy consumed; E_p = energy consumed as a factor in production (that is, energy used in industrial and transportation sectors); and E_c = energy consumed as a consumer good, mainly in domestic households and services. While E_p is more directly related to industrial growth, E_c is an indirect result of rising living standards brought about through more intense use of E_p. In India, only 30 per cent of the total energy is consumed in productive sectors, the rest being residential consumption. The proportion of E_p is expected to increase rapidly as economy progresses.

10.4 *Methodology.* Starting with available information, the basic method employed has been to make an overall projection of total energy consumption and total electricity consumption relating these to the hypothesis of economic development. The overall figure thus obtained serves as a useful frame of reference for dimensional analysis and as a guide for further sectoral breakdowns which can then be aggregated to give a more accurate estimate of total demand. Projections of energy demand by means of a selective analysis of the various economic sectors is a more accurate way of ascertaining the distribution of total energy consumption by type of fuel and of examining the possibility of replacing one type of fuel by another. In the more developed countries, there is no great difference between the method by sectors and the overall method, but in a country like India, the change in economic structure and the scope it provides for a more rapid substitution of traditional fuels by commercial variety is a major factor to be taken into account. The sectoral analysis has been carried further into certain specific activities within that sector viz. iron and steel, cement etc. in the industrial sector, and road and rail transport in the transportation sector. The next point to be examined is the breakdown of total energy by type of energy. Since electricity as a source of mechanical power is a very special and characteristic form of energy, estimates of electricity demand are made separately for different sectors, and then subtracted from the total energy demand to obtain requirements of coal and petroleum products. By isolating such exclusive sources of energy as motor spirit for automobiles, kerosene for lighting and coke for iron smelting etc., the aggregate demand for coal and oil has been further broken down into its coal and oil constituents on certain broad assumptions as regards the future possibilities of their substitution. The demand for electricity is also broken down into thermal, hydro and nuclear sources and an estimate made of installed capacities necessary to meet this demand.

The model of economic growth adopted here aims at roughly doubling the per capita income from Rs. 281 in 1955-56 to Rs. 564 in 1975-76. This follows the line of development postulated in the Second Five Year Plan with a slight modification towards the end of the 20-year period.

10.5 *Overall Projections.* This is concerned mainly with overall energy projections on the basis of certain demand elasticities and their breakdown into broad sectoral requirements. Total effective energy demand is seen to grow from 131 mtce in 1955 to about 316 mtce by 1975 (Table 3.12.2). The growth of industrial energy is expected to be more than five-fold, while the requirements of transportation will increase less than three-fold from about 12 mtce to 28 mtce. Because of the rapid growth of the industrial and transportation sectors, the ratio of primary to secondary energy is expected to go up sharply to 3.6 in 1975 from 0.47 in 1955: primary energy will have overtaken secondary energy sometimes between 1960 and 1965. The domestic requirements at present are almost entirely met by secondary fuels, only about 4 per cent of the demand being met by primary sources. By 1975, over 40 per cent of the demand is expected to be met by coal—or petroleum-based fuels, if the whole of the secondary energy complement of domestic requirements is replaced by primary energy substitutes by that date.

10.6 *Electricity.* Demand for electricity not only tends to grow more rapidly than that of other types of energy but also at a much higher rate than net national output. This means that there is a constant increase in consumption of electricity per unit of national product. In India, the number of kWh per rupee of net output increase from 0.0766 in 1950 to 0.110 in 1956. In other countries, the relative rate of growth can be judged from the fact that while GNP increases at the rate of about 3-4 per cent annually, electricity consumption usually doubles itself in about ten years.

Since industry is the main consumer of electricity, the relationship between the index of industrial production and power generation can provide a reasonably firm basis for assessing future power requirements. On this basis, effective requirements of electricity have been worked out at 17,000, 33,600, 61,500 and 108,000 million kWh by 1960, 1965, 1970 and 1975 respectively. Broad sectoral breakdowns are obtained for as many sectors as possible beginning, of course, with the industrial sector. Here, the notion of "co-efficient of electrification", i.e. the number of kWh per unit input of total energy, is found extremely useful in assessing the relative requirements of electricity in different industries. The requirements of households for lighting and heat have been derived on the basis of certain assumptions with regard to the growth of urbanization and rural electrification, and higher consumption due to rising living standards. The use of electricity in households is essentially a function of the degree of urbanization and so is its use in public (street lighting, waterworks, etc.) and commercial services. Traction accounts for a negligible percentage of electricity consumption at present but with growing densities of railway traffic and the general need for raising the overall efficiency of utilization of fuels on the railways, this proportion is expected to go up and may account for about a third of the total traction capacity by 1975-76. All these sectoral demands, when aggregated, give the total effective demand for electricity which is found to be fairly close to the figure obtained from the 'overall' approach. The sectoral breakdowns are only approximate at this stage but they provide an electrical framework corresponding to the total energy framework derived earlier.

10.7 *Consumption in households.* Although the total domestic requirements of heat and light in the country can be estimated with a reasonable degree of accuracy, an element of guesswork is involved in disaggregating the total into its components by type of energy. Domestic heat can be provided by coal (soft coke and coal gas), kerosene and bottled gas, and electricity. Starting with urban households, it is assumed that their entire heat requirements will be met by primary fuels by 1975. In rural households, wood and dung will continue to be the main source of heat for cooking until such time as they are replaced by coal-based fuels (which is unlikely to be the case before 1975). Lighting will be mainly by electricity in urban areas and by kerosene in rural households. These estimates need not be taken as final, for a great deal will depend on the nature and quality of primary fuels developed in the future for domestic use, for not all of them can be considered as adequate substitutes for each other. The general assumption is that (1) expansion of coal gas and LPG supplies will lead to a decline in demand for kerosene (for cooking); and (2) expansion of soft coke supplies will not materially affect the demand for kerosene although soft coke will certainly replace wood fuel and cow-dung if the price is favourable. The whole pattern of domestic energy consumption in India will be decided by the speed with which primary energy substitutes, in the form of coke or gas, are made available to consuming households in the near future. The Council has recently studied this problem in some detail and recommended early and prompt official action in this regard (vide *Domestic Fuels in India*, NCAER, 1959).

10.8 *Transportation energy*. It is useful to consider this under two main categories, rail and road traffic, which between them account for over 90 per cent of the total energy consumed in transportation. Rail traffic can be further sub-divided into industrial and non-industrial (that is, mainly agricultural), the former having a close correlation with the index of industrial production, and the latter with total consumption of foodgrains in the country. Passenger traffic has been assumed to grow about half as fast as goods traffic. On this basis, estimates of total coal requirements work out as 17, 23, 31 and 42 million tons by 1960, 1965, 1970 and 1975 respectively. These would be the total requirements if the whole of the traffic were carried by steam locomotives. However, the need to improve the overall efficiency of the system and reduce consumption of high grade coal (in steam locomotives) is expected to bring about a shift from steam to more efficient modes of traction. Electrification is considered more suitable for Indian conditions than dieselization, and it is assumed that (1) 30 per cent of the tractive capacity will be electrified by 1975 and (2) shunting services will be operated exclusively by diesel traction. On this basis, about half the total energy requirements are expected to be met by coal (i.e. steam traction) and the rest by electricity and diesel.

Road traffic has been estimated by deducting railway traffic from the total long-distance traffic that is expected to be generated within the economy in the next few decades. It will probably reach 165 million tons by 1975-76, a considerable increase from its current size of less than 10 million tons. The total traffic is further sub-divided into long-distance, feeder and local traffic and the number of trucks required for each derived on the basis of certain coefficients. It is assumed that the whole of the long-distance traffic will be carried by diesel vehicles in future, the entire local traffic by petrol vehicles, and the feeder traffic by a combined fleet of diesel and petrol vehicles. Similar estimates are made for passenger buses and motor cars. This detailed breakdown of vehicles serves as the basis for calculating diesel and petrol requirements. Shipping and aviation requirements can be added to this to give total transportation energy by type of fuel.

10.9 *Energy in Industry.* Demand for energy in industry is considered under four principal heads, namely, mining, factory establishments, small enterprises and construction. Of these, factory establishments are certainly the most energy-intensive, but since the patterns of energy consumption vary as between different kinds of industry, a more detailed breakdown is attempted by sub-dividing this main manufacturing block into metal, non-metal, textiles and miscellaneous industries. Using suitable unit co-efficients, their requirements of total energy have been worked out as also their electricity needs. The non-electricity demand, which is mainly heat, has to be met by either coal or petroleum, and this breakdown is effected on the basis of certain assumptions as regards their comparative advantages (price, efficiency etc.) in future. The question of availability of indigenous oil supplies, a crucial factor in assessing the growth of petroleum consumption, is largely a matter of speculation and may ultimately decide the degree of shift away from coal that is currently evident in the world at large. In countries with roughly the same coal/petroleum pattern as India's, the petroleum coefficient has been found to be growing at a rate of 4-6 per cent annually. A lower rate has been adopted in this study.

10.10 *Energy in Agriculture.* Energy inputs in agriculture are, roughly speaking, a function of the level of agricultural techniques adopted, the levels varying not only from country to country but also from region to region within the same country. Countries with a high level of agricultural technology possess, with few exceptions, also high levels of industrial and general economic development, and vice-versa. The indirect energy inputs which flow to agriculture through other sectors (such as fertilizers) have already been taken care of; the direct inputs accrue through mechanization of cultivation and of irrigation practices. The area under irrigation is expected to go up to 112 million acres by 1975-76 and it is assumed that roughly half of this will come under mechanical cultivation. The number of tractors required will thus be about 560,000 in 1975-76, which is roughly the number Soviet Union had in 1938-39. If the Indian food problem is tackled as a measure of the most serious economic and political emergency, then the target of 560,000 tractors by 1975 'may actually be an under-estimate.

An additional small number of tractors will be required for reclamation purposes. Their number, however, will not exceed a thousand since about a million acres of waste land are expected to be reclaimed annually. The requirements of oil (for all types of tractors) will reach one million tons by 1975-76. In addition, about half a million tons will be needed by oil engines for pumping.

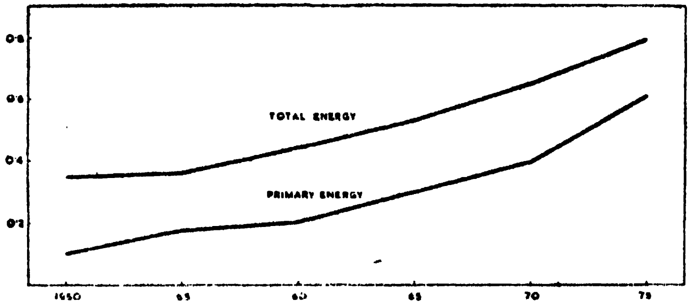
10.11 These sectoral projections can be summated to give aggregate requirements of energy by form of energy viz. coal, electricity and petroleum. Electricity has at least three conventional sources—coal, hydro power and oil—and may well be derived from nuclear sources by the time we reach the end of the third quarter of this century. Of these four likely sources, coal and hydro power will continue to be the more important ones, and a comparative assessment of these two types of generation indicates that while, in the short run, thermal power may have a temporary advantage over hydro power, the balance is likely to swing in favour of the latter in the near future. It is therefore assumed that the growth of hydro power will be relatively more rapid than that of thermal power. It is also assumed, on the basis of an assessment of conventional energy resources, that "threshold conditions for the entry of nuclear power are slowly taking shape in the country" and that nuclear power may constitute about 9 per cent of the total power generated in 1975-76. After allowing for transmission losses etc the pattern of generation by source of energy has been finally determined which indicates that 48 per cent of output will be hydro-electricity, about 41 per cent will be derived from coal, 2 per cent from petroleum sources (including natural gas) and the remaining 9 per cent will be nuclear. Total installed capacity will be 36.4 million kW in 1975-76, of which 16.5 will be steam, 16.7 will be hydro, and 1.92 will be nuclear.

10.12 Estimates of gross requirements follow more or less automatically and are given in Table 9.10.1. It is interesting to note that while the average rate of increase of total energy is of the order of 5 per cent per annum, that of primary energy will be about 10 per cent. During the Second and Third Plans the rate of growth is expected to be higher at about 16 and 12 per cent respectively, mainly because of the low base from which the energy economy is starting and also because of the relatively heavy investment in energy-intensive capital industries during this period.

In percentage terms, the share of coal is expected to fall to about 71.0 from 82.4 per cent in 1950 and 79.5 per cent in 1955. This is, of course, in accord with the worldwide trend against coal that has been in evidence since the beginning of the Second World War. The fall in the coal component is, however, being taken up by hydro power instead of petroleum. Actually, contrary to popular impression, the share of petroleum is expected to be more or less steady at about 13 to 14 per cent. The Indian energy economy in 1975 will be substantially a coal-based economy, and even by A.D. 2000 it may have as high a proportion of coal as 55 to 60 per cent. It may perhaps be mentioned here that as recently as 1946, coal provided nearly half of all the fuel energy consumed in the United States.

FIGURE 15

PER CAPITA CONSUMPTION OF PRIMARY AND TOTAL ENERGY, 1950 TO 1975.



In per capita terms (Fig. 15), primary energy consumption is expected to reach 0.62 tce in 1975 from the current level of less than 0.20 tce. Considering that the level of consumption as recently as 1950 was only 0.10 tce, the six-fold increase in twentyfive years amounts to an energy 'explosion' unprecedented in our history and is a measure of industrial and economic development that the future is expected to bring to India. Despite this considerable increase in consumption, the average per capita level in 1975 will only be about one-fifteenth of the current per capita consumption in the United States.

TABLES

TABLE I

CONSUMPTION OF PRIMARY AND SECONDARY ENERGY IN INDIA BY SECTORS, 1950

(thousand tce)

	Net coal[a]	Electricity	Net petroleum[b]	Total primary	Total secondary	Total energy
1. Agriculture and Allied Activities	276	145	153	574	—	574
2. Industry						
(a) Metal	3,863	750	72	4,685	22	4,707
(b) Non-metal	1,302	348	32	1,682	8	1,690
(c) Textiles	1,778	1,293	210	3,281	5	3,286
(d) Rest	3,669	1,036	651	5,556	200	5,556
Total Industry	10,612	3,427	965	15,004	235	15,239
3. Transport						
(a) Railways	8,319	430	95	8,844	7	8,851
(b) Automobiles	—	—	895	895	—	895
(c) Aviation	—	—	109	109	—	109
(d) Shipping	313	—	45	358	—	358
Total Transport	8,632	430	1,143	10,205	7	10,212
4. Domestic						
(a) Heat	1,440	70	133	1,643	87,930	89,573
(b) Light	—	401	1,195	1,596	—	1,596
Total Domestic	1,440	471	1,328	3,239	87,930	91,169

(Contd. overleaf)

TABLE I—*contd.*

	Net coal[a]	Electricity	Net petroleum[b]	Total primary	Total secondary	Total energy
5. Public and Commercial Services	348	501	—	849	—	849
6. Miscellaneous and unaccounted for	208	—	120	328	21	349
Effective Consumption	21,516	4,974	3,709	30,199	88,193	118,392
7. Transport of Energy						
(a) Coal	1,680	—	30	1,710	—	1,710
(b) Electricity	—	630	—	630	—	630
(c) Petroleum	148	—	8	156	—	156
Total transport of energy	1,828	630	38	2,496	—	2,496.0
8. Extraction and Processing of Energy						
(a) Collieries	2,310	270	41	2,621	—	2,621
(b) Electric generation	—	225	—	225	—	225
(c) Refineries	—	3	38	41	—	41
Total Extraction and Processing	2,310	498	79	2,887	—	2,887
Net Consumption	25,654	6,102	3,826	35,582	88,193	123,775
9. Losses	666	105	9	780	—	780
Gross Consumption	26,320	6,207	3,835	36,362	88,193	124,555

[a] Excluding coal used in electricity generation.

[b] Excluding petroleum used in electricity generation.

— nil or negligible.

SOURCE: National Council of Applied Economic Research.

TABLE II

CONSUMPTION OF PRIMARY AND SECONDARY ENERGY IN INDIA BY SECTORS, 1955

(thousand tce)

	Net coal[a]	Electricity	Net petroleum[b]	Total primary	Total secondary	Total energy
1. Agriculture and Allied Activities	723	199	255	1,177	—	1,177
2. Industry						
(a) Metal	3,630	953	67	4,650	22	4,672
(b) Non-metal	1,976	752	45	2,773	9	2,782
(c) Textiles	1,954	1,776	225	3,955	6	3,961
(d) Rest	3,516	1,800	987	6,303	200	6,503
Total Industry	11,076	5,281	1,324	17,681	237	17,918
3. Transport						
(a) Railways	9,717	415	68	10,200	4	10,204
(b) Automobiles	—	—	1,367	1,367	—	1,367
(c) Aviation	—	—	169	169	—	169
(d) Shipping	279	—	68	347	—	347
Total Transport	9,996	415	1,672	12,083	4	12,087
4. Domestic						
(a) Heat	1,844	123	206	2,173	93,425	95,598
(b) Light	—	542	1,854	2,396	—	2,396
Total Domestic	1,844	665	2,060	4,569	93,425	97,994

(Contd. overleaf)

TABLE II—*contd.*

	Net coal[a]	*Electricity*	*Net petroleum*[b]	*Total primary*	*Total secondary*	*Total energy*
5. Public and Commercial Services	435	607	—	1,042	—	1,042
6. Miscellaneous and unaccounted for	671	—	171	842	67	909
Effective Consumption	24,745	7,167	5,481	37,393	93,733	131,127
7. Transport of Energy						
(a) Coal	2,110	—	44	2,154	—	—
(b) Electricity	—	716	—	716	—	—
(c) Petroleum	218	—	11	229	—	—
Total transport of energy	2,328	716	55	3,099	—	3,099
8. Extraction and Processing of Energy						
(a) Collieries	2,149	304	39	2,492	—	—
(b) Electric generation	—	355	—	355	—	—
(c) Refineries	9	32	271	312	—	—
Total extraction and processing	2,158	691	310	3,159	—	3,159
Net Consumption	29,231	8,574	5,846	43,651	93,733	137,384
9. Losses	922	138	128	1,188	—	1,188
Gross Consumption	30,153	8,712	5,974	44,839	93,733	138,572

[a] Excluding coal used in electricity generation.

[b] Excluding petroleum used in electricity generation.

— nil or negligible.

SOURCE: National Council of Applied Economic Research.

TABLE III

PROJECTED DEMAND FOR PRIMARY ENERGY IN INDIA, 1960

(thousand tce)

	Net coal[a]	*Electricity*	*Net petroleum*[b]	*Total primary*
1. Agriculture and Allied Activities	1,000	378	450	1,828
2. Industry				
(a) Metal and Non-metal	16,960	6,100	435	23,495
(b) Textiles	2,290	2,310	342	4,942
(c) Rest	4,890	2,690	1,560	9,140
Total Industry	24,140	11,100	2,337	37,577
3. Transport				
(a) Railways[c]	14,040	840	137	15,017
(b) Automobiles	—	—	3,150	3,150
(c) Aviation	—	—	280	280
(d) Shipping	450	—	100	550
Total Transport	14,490	840	3,667	18,997
4. Domestic				
(a) Heat	4,582	238	420	5,240
(b) Light	—	813	2,573	3,386
Total Domestic	4,582	1,051	2,993	8,626
5. Public and Commercial Services	600	1,072	—	1,672
6. Miscellaneous and unaccounted for[d]	1,000	—	250	1,250
Effective Consumption	45,812	14,441	9,697	69,950

[a] Excluding coal used in electricity generation.

[b] Excluding petroleum used in electricity generation.

[c] Including coal and petroleum carried by Railways.

[d] Including construction.

— nil or negligible.

SOURCE : National Council of Applied Economic Research.

TABLE IV

PROJECTED DEMAND FOR PRIMARY ENERGY IN INDIA, 1965

(thousand tce)

	Net coal[a]	*Electricity*	*Net petroleum*[b]	*Total primary*
1. Agriculture and Allied Activities	1,500	674	780	2,954
2. Industry				
(a) Metal and Non-metal	28,810	12,000	890	41,700
(b) Textiles	2,590	3,100	492	6,182
(c) Rest	7,620	4,900	2,780	15,300
Total industry	39,020	20,000	4,162	63,182
3. Transport				
(a) Railways[c]	16,560	1,560	378	18,498
(b) Automobiles	—	—	4,950	4,950
(c) Aviation	—	—	460	460
(d) Shipping	900	—	150	1,050
Total transport	17,460	1,560	5,938	24,958
4. Domestic				
(a) Heat	9,088	462	910	10,460
(b) Light	—	1,232	2,847	4,079
Total Domestic	9,088	1,694	3,757	14,539
5. Public and Commercial Services	900	1,700	—	2,600
6. Miscellaneous and unaccounted for[d]	1,500	—	375	1,875
Effective Consumption	69,468	25,628	15,012	110,108

[a] Excluding coal used in electricity generation.

[b] Excluding petroleum used in electricity generation.

[c] Including coal and petroleum carried by Railways.

[d] Including construction.

— nil or negligible.

SOURCE : National Council of Applied Economic Research.

TABLE V

PROJECTED DEMAND FOR PRIMARY ENERGY IN INDIA, 1970

(thousand tce)

	Net coal[a]	*Electricity*	*Net petroleum*[b]	*Total primary*
1. Agriculture and Allied Activities	2,500	1,136	1,312	4,948
2. Industry				
(a) Metal and Non-metal	44,930	21,100	1,870	67,900
(b) Textiles	2,960	4,000	740	7,700
(c) Rest	11,180	7,850	4,620	23,650
Total Industry	59,070	32,950	7,230	99,250
3. Transport				
(a) Railways[c]	19,030	2,600	788	22,418
(b) Automobiles	—	—	8,250	8,250
(c) Aviation	—	—	750	750
(d) Shipping	1,500	—	225	1,725
Total Transport	20,530	2,600	10,013	33,143
4. Domestic				
(a) Heat	18,673	857	1,250	20,780
(b) Light	—	1,798	3,152	4,950
Total Domestic	18,673	2,655	4,402	25,730
5. Public and Commercial Services	1,500	2,580	—	4,080
6. Miscellaneous and unaccounted for[d]	2,500	—	600	3,100
Effective Consumption	104,773	41,921	23,557	170,251

[a] Excluding coal used in electricity generation.

[b] Excluding petroleum used in electricity generation.

[c] Including coal and petroleum carried by Railways.

[d] Including construction.

— nil or negligible.

SOURCE: National Council of Applied Economic Research.

TABLE VI

PROJECTED DEMAND FOR PRIMARY ENERGY IN INDIA, 1975

(thousand tce)

	Net coal[a]	*Electricity*	*Net petroleum*[b]	*Total primary*
1. Agriculture and Allied Activities	4,000	1,800	2,280	8,080
2. Industry				
(a) Metal and Non-metal	64,130	31,500	3,375	99,005
(b) Textiles	3,380	5,070	1,120	9,570
(c) Rest	18,450	13,800	8,750	41,000
Total Industry	85,960	50,370	13,245	149,575
3. Transport				
(a) Railways[c]	20,700	4,190	1,508	26,398
(b) Automobiles	—	—	13,600	13,600
(c) Aviation	—	—	1,200	1,200
(d) Shipping	2,500	—	340	2,840
Total Transport	23,200	4,190	16,648	44,038
4. Domestic				
(a) Heat	37,305	1,625	1,670	40,600
(b) Light	—	2,840	3,472	6,312
Total Domestic	37,305	4,465	5,142	46,912
5. Public and Commercial Services	3,000	4,110	—	7,110
6. Miscellaneous and unaccounted for[d]	4,000	—	900	4,900
Effective Consumption	157,465	64,935	38,215	260,615

[a] Excluding coal used in electricity generation.

[b] Excluding petroleum used in electricity generation.

[c] Including coal and petroleum carried by Railways.

[d] Including construction.

— nil or negligible.

SOURCE: National Council of Applied Economic Research.

NOTES AND REFERENCES

NOTES AND REFERENCES

Coefficients of Conversion: The following coefficients of conversion have been used in this study: 1 pound of coal = 11,000 BTU; 1 ton of coke = 0.9 tons of coal; 1 ton of petroleum = 1.5 tons of coal; 58,000 cubic feet of gas = 1 ton of coal; electricity conversion coefficients vary from year to year, depending upon the thermal efficiencies of power statistics (vide para 4.11 and Table 4.11.2).

'World Energy Requirements', *Peaceful Uses of Atomic Energy*, Department of Economic and Social Affairs, United Nations, Vol. I, pp. 1-29; United Nations Statistical Papers J-1; *Statistical Yearbook* (1955), United Nations.

World utilization of useful heat and power in 1952 was as follows:

(Billion mWh)

	Useful heat	*Useful power*	*Total*
Agriculture	—	0.3	0.3
Transport	—	0.8	0.8
Industry	5.2	0.6	5.8
Households etc.	2.9	0.4	3.3
Total	8.1	2.1	10.2

SOURCE: *Peaceful Uses of Atomic Energy*, Vol. I, 1956, p. 5.

3 Power requirements (kWh) for certain electro-process materials (per ton of product) are roughly as follows: titanium metal, 40,000; aluminium metal, 18,000; 95 per cent silicon metal, 17,500; electrolytic magnesium, 16,000; 35 per cent hydrogen peroxide (100 per cent basic) 16,000; electrolytic manganese, 10,200; silicon carbide, 8,600; 70 per cent ferro-tungsten, 7,600; sodium chlorate, 5,200; rayon, 5,200; phosphoric acid (via electric furnace) 3,900; electrolytic zinc, 3,400; chlorine, 3,000. [Adapted from chart of 'Process Power Requirements', *Chemical Engineering*, March 1951, p.115.]

4 'As the normal functioning of an underdeveloped economy does not generate growth, whatever growth occurs must be the result of factors external to the growth-determining rotations. These external factors will be called 'shocks'. Shocks are not necessarily random events; they can be such items

as exceedingly favourable weather conditions leading to excellent harvests, discoveries of new material sources and production processes, wars, foreign investments, economic aid, or the impact of international trade and government policies. In particular, these shocks may be the result of conscious policy decisions... the strategy of economic development planning consists of first identifying the shocks which will result in an increase in per capita income, and then administering such shocks until the cumulative effect of the disturbances transforms the economy from an underdeveloped economy to one in which self-sustained growth occurs.' HYMAN P. MINSKY, 'Indicators of the Developmental Status of an Economy', *Economic Development and Cultural Change*, January 1959.

5 PUTNAM P. C., *Energy in the Future*, 1953, pp. 72-96.

6 'In an underdeveloped economy, whenever an increase in real GNP occurs, either it is not sustained or it is quite readily offset by a rise in population. A limiting form of underdevelopment is found in the stagnant economies in which net savings, net investment, and the net change in population are all zero. A particular type of stagnant economy is the underdeveloped conomy in which the per capita real gross national product is so low that a large proportion of the population is at or close to the biological subsistence level. In addition to the subsistence stagnant state, stagnation can occur at per capita incomes higher than the biological subsistence level. This occurs when an economy reverts to the underdeveloped state after a period in which per capita incomes are increasing and population growth does not offset the cumulated increase in real per capita income.' HYMAN P. MINSKY, *Economic Development and Cultural Change*, January 1959.

7

ENERGY INPUT AND GROSS NATIONAL PRODUCT

Year	*Total primary*[a]	*Total secondary*[a]	*Total energy*[a]	*Total GNP*[b]	*Energy per million rupees*[a]
1950	30.2	88.2	118.4	88.7	1.335
1951	30.9	88.9	119.8	91.2	1.313
1952	32.2	90.3	122.5	94.7	1.293
1953	33.7	91.4	125.2	100.3	1.248
1954	35.2	92.6	127.8	102.8	1.242
1955	37.4	93.7	131.1	104.8	1.251
1956	40.5	94.9	135.4	110.0	1.231

[a] Thousand tons of coal equivalent; SOURCE: National Council of Applied Economic Research.

[b] Million rupees at 1948-49 prices; SOURCE: *Estimates of National Income*, 1958, Central Statistical Organization.

8

PRODUCTIVITY AND THE AMOUNT OF POWERED EQUIPMENT INSTALLED PER WAGE-EARNER, IN THE MANUFACTURING INDUSTRIES OF SELECTED COUNTRIES

Country	*Year*	*Output per production worker man-hour (international units)*	*Installed HP per worker*
U.S.	1899	0.382	2.18
	1909	0.401	2.88
	1925	0.803	4.37
	1929	0.904	4.91
	1939	1.187	6.42
	1947	1.434	8.10
U.K.	1907	0.191	1.37
	1924	0.293	2.38
	1930	0.337	2.83
France	1931	0.281	2.50
Germany	1933	0.429	2.70
U.S.S.R.	1928	0.200	1.30
	1934	0.170	1.80

SOURCE: SEYMOUR MELMAN, *Dynamic Factors in Industrial Productivity*, Oxford, 1956, p. 212.

9 "The process of economic development characteristically involves an increase in the proportion of the total national product originating outside agriculture. As per capita output rises, the output of agriculture rises less than in proportion to total national output; while the output of industry, and the non-agricultural part of the economy generally, rises faster than overall output." [*Second Five Year Plan*, Planning Commission, Government of India, 1956, p. 13.] Egbert Devries has derived from the data on thirty-four countries the generalization that for every 10 per cent increase in per capita real income, the fraction of national income arising from agriculture drops by 1½ percentage points. A similar generalization elaborated in particular by Colin Clark (*The Conditions of Economic Progress*) is that economic development involves faster growth in the secondary and tertiary sectors of the economy than in the primary (extractive) sector.

10 *Second Five Year Plan*, pp. 11-5; COALE A. J. and HOOVER E. M., *Population Growth and Economic Development in Low-Income Countries*, 1958, pp. 121-3.

11 'Continued growth of national income and employment requires simultaneous development all over the economy. In agriculture and allied pursuits, the net output per worker is at present barely one-fifth of that in mining and factory establishments, and it is one-third of the net output per worker in the trade and services sector. Development involves a transfer of part of the working force from agriculture to secondary and tertiary activities, but this, in turn, pre-supposes an increase in productivity in agriculture itself, if the food and raw material requirements of a development economy are to be met. Improvements in agriculture through irrigation, supply of better seed and fertiliser and through adoption of more efficient techniques are thus the basis on which the secondary and tertiary sectors have to be expanded. These latter call for relatively large investment per worker employed, so that the degree of shift that can be secured is ultimately related to the amount of investment effort that the economy can put forth.' *Second Five Year Plan,* pp. 12-3.

12 The consumption pattern has been given in detail in Tables I and II, to which a reference may be made. Percentage consumption for 1956 is as indicated below:

Sector	*Percentage consumption of energy*
Agriculture	0.85
Industry[a]	13.50
Transport[b]	9.25
Domestic	69.50
Miscellaneous services	1.60
Effective consumption	94.70
Transport & Processing of energy	4.70
Net consumption	99.40
Losses[c]	0.60
Gross consumption	100.00

[a] excluding energy-processing industries.
[b] excluding transport of energy.
[c] lost in conversion of energy.

SOURCE: National Council of Applied Economic Research.

13 Energy consumption originating in industrial sectors in the United States, 1947:

Sector	*Energy consumption* 10^{12} BTU
Agriculture[a]	887
Mining and quarrying[b]	1,114
Transport[c]	8,640
Manufacturing	9,611
Domestic and commercial	9,504
Military	269
Non-fuel use	1,345
Miscellaneous, losses and unaccounted for	2,146
Total internal consumption	33,516
Exports	3,007
Total supply	36,523

[a] including forestry and fisheries
[b] including crude petroleum and natural gas
[c] including pipelines

SOURCE: MASON E. S. et al., 'Energy Requirements and Economic Growth', *Peaceful Uses of Atomic Energy*, p. 57.

14 *Domestic Fuels in India*, National Council of Applied Economic Research, 1959.

15 'After analysing the historical behaviour and international situation, it seems advisable to formulate a tentative hypothesis on the behaviour of consumption of total energy in relation to economic activity, mainly on account of the indications which may be derived as to future energy requirements. In the initial stages of development, consumption of energy generally grows at a slower rate than the gross product and therefore unit consumption will decline (product elasticity well below unity). Later, at intermediate levels of development—where there are marked changes in the structure of production, mainly consisting in the greater expansion of industry and other activities whose energy inputs are proportionately higher and in a more intense growth of residential consumption—supply requirements will increase at least as intensely as the gross product (product elasticity close to unity). Finally, when a high degree of development is reached and the various production sectors acquire a more stable structure, unit consump-

tion will again decline, this time owing to the possibility of improved efficiency in the use of energy and to a partial saturation of residential demand.' *Energy in Latin America*, U.N. Economic Commission for Latin America, 1957, p. 26.

16 ROBINSON E. A. G. and DANIEL G. H., 'The World's Need for a New Source of Energy', *Peaceful Uses of Atomic Energy*, pp. 39-40

17 'The socialist pattern of society is not to be regarded as some fixed or rigid pattern. It is not rooted in any doctrine or dogma. Each country has to develop according to its own genius and traditions.... It is neither necessary nor desirable so that the economy should become a monolithic type of organization offering little play for experimentation either as to forms or as to modes of functioning.... Economic policy and institutional changes have to be planned in a manner that would secure economic advance along democratic and egalitarian lines.' *Second Five Year Plan*, pp. 23-4.

18 The most obvious indicator of the development status of an economy is the level of per capita real gross national product. Even though there is no simple way of equating per capita real gross national product with economic welfare (presumably, the purpose in fostering economic development is to increase economic welfare) it remains the best single indicator of where an economy is. In this study, the generic term *income* is generally used in place of the technical term *gross national product*.

19 *Second Five Year Plan*, p. 11.
This study was more than half way through before it became apparent that the population growth was faster than that assumed in this model. Since total primary energy consumption is more directly related to total output than per capita incomes, the projections of total energy demand remain substantially unaffected, particularly as, even by 1975, about 85 per cent of the total primary consumption will still be in non-domestic sectors. For a detailed discussion of the influence of population growth on economic development, see COALE A. J. and HOOVER E. M., *Population Growth and Economic Development in Low-Income Countries*, Princeton, 1958.

20 In the U.S.A., it was less than 2.5 per cent in 1947 (MASON E.S. et al, *Peaceful Uses of Atomic Energy*, p. 57); in Latin America, it varies between 1.5 to 2 per cent (*Energy in Latin America*).

21 PUTNAM P.C., *Energy in the Future*, 1953, pp. 72-96.

22 '... while the production of pig iron and ferro-alloys has increased 34 per cent in the last seven years, the coal equivalent of coke charged to the blast furnaces has increased only 23 per cent. This substantial saving has occurred despite a marked deterioration of coking coal quality.... Although steel production has increased by a third, the consumption of coal other than coking coal has actually declined by a quarter....' *Steel Review*, British Iron and Steel Federation, April 1956, pp. 1-2.

23 British steel industry's fuel and power consumption is given in the table

below. The consumption is in terms of coal equivalent, but the various forms cannot, however, be added together since the gas, tar and creosote pitch and one-third of electricity are produced in the industry from the basic fuels also included in the table.

	1948	1955	*Increase* (per cent)
Consumption (mtce)			
Coke: in blast furnaces	16.62	20.42	23
Other uses	0.39	0.43	10
Coal other than coking	7.66	5.78	—25
Heavy fuel oil	0.98	2.01	105
Other oil	0.04	0.12	200
Tar	0.08	0.41	413
Creosote-pitch	0.16	0.53	231
Coke oven gas	2.75	4.13	50
Electricity	2.42	3.47	43
Production (million tons)			
Pig iron and ferro-alloys	9.28	12.47	34
Crude steel	14.87	19.79	33

SOURCE: *Steel Review*, April 1956, p. 2.

24 *Report of the Expert Committee on Coal Consumption in Railways*, Ministry of Railways, Govt. of India, 1958, pp. 85-92.

25 *The Times Review of Industry*, June 1959.

26

EFFICIENCIES OF HOUSEHOLD COOKING APPLIANCES

Fuel	*Efficiency* (per cent)	*Effective price* (nP/thousand kcal)
Soft coke	28	3.93
Gas (coal)	60	6.30
Kerosene	48	9.35
Charcoal	28	11.40
Wood	17	11.70
Electricity	76	15.40
Dung	11	22.70

SOURCE: *Domestic Fuels in India*, National Council of Applied Economic Research, 1959, p. 23.

27

DOMESTIC HEAT CONSUMPTION IN INDIA, 1956

(mtce)

	Urban	*Rural*	*Total*
Coal[a]	2.0	—	2.0
Electricity	0.2	—	0.2
Kerosene	0.3	—	0.3
Dung	4.0	35.0	39.0
Firewood			
Solid[b]	8.5	23.5	32.0
Waste	5.0	18.5	23.5
Total	20.0	77.0	97.0

[a] including coke.
[b] including charcoal.
SOURCE: *Domestic Fuels in India,* National Council of Applied Economic Research, 1959, p. 17.

28 The percentage contribution of wood-fuel to total energy system fell from 98 per cent in 1800 to 5 per cent in 1950 in the U.S.; 99 (1860) to 35 per cent (1950) in the U.S.S.R.; 22 (1860) to 4 per cent (1950) in Germany; 30 (1920) to 15 per cent (1940) in Argentina; and 94 (1880) to about 72 per cent (1945) in India. [THIRRING HANS, *Power Production,* Harrap, 1956, p. 220.]

29 Industrial production is expected to grow at a rate of about 7-8 per cent annually during the next two or three plans. During the Second Plan, the steel capacity was to be almost quadrupled to 6 million tons (of crude steel); provisional targets for the Third and Fourth Plans have been fixed at 10.5 and 16 million tons respectively.

30 *Electrical Power Expansion in the Third Plan in Relation to Energy development in India* (mimeographed), Planning Commission, 1958.

31 *Preliminary Report of the Committee on Requirements and Utilisation of Coal* (mimeographed), Ministry of Production, Government of India, July 1957.

32 *First Five Year Plan for Development of the National Economy of the People's Republic of China in 1953-1957*, Foreign Languages Press, 1956, p. 34.

33 *Ibid.*, p. 48.

34 *Energy in Latin America,* pp. 30-3;
'A relationship between the change in total fuel consumption and the

change in output of manufacturing industry (for data covering 1929-50) suggests that for every 1 per cent increase in production there is a 0.81 per cent increase in energy consumption, which is partly offset by a tendency for consumption to fall by 0.6 per cent every year. A broader generalisation is that consumption of primary fuel increases over time by about 0.6 per cent for every 1 per cent increase in industrial activity.' ROBINSON and DANIEL, *Peaceful Uses of Atomic Energy*, Vol. I, pp. 39-41.

35 A detailed breakdown of the industrial sector is given in Table 7.1.2.

36 DANIEL G. H., 'The Energy Requirements of the United Kingdom', *Peaceful Uses of Atomic Energy*, Vol. I, p. 242.

37 ROBINSON E.A.G. and DANIEL G.H., *Peaceful Uses of Atomic Energy*, Vol. I., p. 45.

38 This may not be strictly true. The current momentum of expansion is expected to be maintained well into the seventies although there may be a slight drop in the rate of industrial development towards the end of this period.

39 *Working Group Report on the Third Plan* (mimeographed), Planning Commission, 1959.

40 This is the normal doubling period in 'developed' countries with more or less stable economies.

41 This empirical rate of growth was assumed also by H.J. BHABHA in his projection of electricity demand up to 1980. ('Atomic Power in India', *Peaceful Uses of Atomic Energy*, Vol. I, p. 107)

42 LAHIRI A. and GHOSAL A., 'Requirements and Resources for Power Generation in India', *Indian Journal of Power and River Valley Development*, December 1958.

43 Projections of industrial sub-sectors (mining, factory establishments, small enterprises and construction) are given in Table 7.1.2. Indices of industrial production, 1960-75, have been estimated on the basis of past correlations (1950 to 1957) and after making suitable adjustments to allow for the variation in weights (owing to changes in the industrial complex).

44 'Heavy' industries comprise (1) chemicals including fertilizers but excluding light chemical works; (2) refractories; (3) cement factories; (4) iron and steel works; (5) copper mining and smelting; (6) re-rolling mills and metal works; (7) miscellaneous mining; and (8) engineering and foundries. The rest of the industries are grouped under 'light' industries. The consumption of electricity in 'heavy' industries is about one-third of the total industrial consumption of electricity. (Vide Tables I and II.)

45 *Energy in India* (mimeographed), National Council of Applied Economic Research, 1959.

46 & 47 *Power Engineer*, Vol. 6, 2, 1956; *Second Five Year Plan*, pp. 341-2,

48 The following table gives the breakdown in terms of population range, and the number of towns and villages to be electrified by 1961:

Population	*Total Numbers*[a]	*Number electrified (March 1956)*	*Number to be electrified (March 1961)*
Over 100,000	73	73	73
50,000-100,000	111	111	111
20,000-50,000	401	366	401
10,000-20,000	856	350	856
5,000-10,000	3,101	1,200	2,659
Less than 5,000	556,565	5,300	13,900
Total	561,107	7,400	18,000

[a] according to 1951 census.

SOURCE: *Second Five Year Plan*, Planning Commission, p. 342.

49

RELATIVE SIZE AND PER CAPITA INCOME LEVELS OF URBAN AND RURAL GROUPS IN INDIA, 1950-51

	Percentage of all-India population	*Per capita income of group, as percentage of all-India per capita income*
Urban	17	209
Rural	83	77
Non-farm rural	16	93
Farm rural	67	74
Cultivators	44	93
Labourers	23	38
Urban combined with non-farm rural	33	153

SOURCE: *Census of* 1951; National Income Committee; All-India Agricultural Labour Inquiry; and *Poona Schedules* of the National Sample Survey.

50

POWER CONSUMPTION IN MADRAS AS COMPARED TO ALL-INDIA

(percentage)

India (1956)	67.0	4.0	18.4	1.5	9.1
Madras (1956-57)	58.8	14.5	20.7	2.0	4.0

51 A comparative analysis of thermal and hydro generation is made in Chapter IX, para 9.5.

52 The installed capacity of hydro power stations is to be almost trebled (from just under 1 to 3 million kW), during the Second Five Year Plan. This is, no doubt, the maximum rate of expansion possible as far as hydro power is concerned. Rates of increase in the subsequent plans are assumed to be progressively diminishing and so will the growth rates of irrigation 'power'.

53 Reserves of coal, mostly low-grade, have been estimated at over 100,000 million tons [LAHIRI A. and GHOSAL A., *Indian Journal of River Valley Development*, December 1958]; reserves of petroleum are, for obvious reason, difficult to estimate, but are not believed to be large.

54 *Report of the Expert Committee on Coal Consumption in Railways*, Ministry of Railways, 1958, p. 91.

55 Detailed requirements of the transport sector including railways are worked out in Chapter VI.

56 See Table 6.7.1. Coal constitutes roughly half of the long-distance traffic generated in 1970 and 1975. Although these figures are tentative, it is clear that coal, most of which is carried by railways, will be a major component of rail traffic in the coming years.

57 *Public Electricity Supply All-India Statistics*, General Review, 1950 to 1956, Central Water and Power Commission.

58 The number of units (kWh) generated per ton of coal amounted to: 930 in 1925; 1450 in 1935; 1600 in 1945; 1780 in 1950; and 2075 in 1965 (estimated). According to the latest announcement of the British Electricity Authority, there was an average increase of about 2 per cent in thermal efficiency during the year ending March 1959. [*Annual Report*, British Electricity Authority, HMSO, 1959.]

59 See Table 3.10.3.

60 *Second Road Development Plan for India*, 1961-81 (draft), Ministry of Transport and Communications, 1959.

61 *Annual Reports*, 1954-55 to 1957-58, Railway Board.

62 *Energy in India* (mimeographed), National Council of Applied Economic Research, 1959.

63 *Fuel Economy on Indian Railways*, Report of the Railway Fuel Economy Inquiry Committee, 1953, p. 12.

64 $y = .73\,x + 5.0$

where y = industrial goods traffic in tons

x = index of industrial production (1951 = 100).

65 $y = .295\,x - .62$

where y = agricultural goods traffic in tons.

x = consumption of foodgrains in tons.

66

PASSENGERS ORIGINATING AND PASSENGER-MILES IN INDIAN RAILWAYS, 1945-57
(millions)

Year	*Passengers*	*Passenger-miles*
1945-46	986	40,046
1946-47	1,078	40,631
1947-48	981	32,150
1948-49	1,114	37,129
1949-50	1,194	38,465
1950-51	1,279	41,159
1951-52	1,204	39,030
1952-53	1,186	36,928
1953-54	1,194	37,096
1954-55	1,236	38,316
1955-56	1,275	38,774
1956-57	1,360	41,678

SOURCE : Railway Board.

67

COAL CONSUMPTION IN INDIAN RAILWAYS, 1926-27—1956-57
(pounds per 1000 gross ton miles)

Year	*Goods*[a] *(B.G.)*	*Passenger*[a] *(B.G.)*
1926-27	139	186
1930-31	132	173
1934-35	127	166
1938-39	137	178
1942-43	150	177
1946-47	163	174
1950-51	159	201
1956-57	153	182

[a] and proportion of mixed.

SOURCE: *Report of the Expert Committee on Coal Consumption in Railways*, p. 36.

68 *Report of the Expert Committee on Coal Consumption in Railways*, p. 85, and Appendix 23, p. 207.

69 "The Committee consider that endeavours should be made to reach a target of at least 30 per cent electric traction, and 20 per cent diesel traction by 1975. This will leave 50 per cent of railway traffic for steam traction which will require 27.5 million tons of coal (including 2.5 million tons for generating thermal power for electrification) against 50 million tons estimated earlier. Thus with 30 per cent electrification and 20 per cent dieselisation, the requirement of coal in 1975 will remain at about the same level as now estimated for 1965-66." [*Report of the Expert Committee on Coal Consumption in Railways*, p. 91]

70 Petroleum fuels constituted less than one per cent of the total energy consumption by the railways during 1950-56.

71, 72 & 73 *Second Road Development Plan for India*, 1961-81. The draft plan has not yet been approved by the Government.

74 About 1.8 million tons, roughly 5 per cent of the total coal despatches from collieries, were carried by road in 1956, statewise distribution being as follows: West Bengal, 919,000 tons; Bihar, 599,000 tons; Assam, 195,000 tons; Orissa, 55,000 tons; and Madhya Pradesh, 41,000 tons. [*Indian Coal Statistics*, Chief Inspector of Mines, Ministry of Labour, 1956.]

75 *Basic Road Statistics*, Ministry of Transport (Roads Wing), 1954-56.

76

REGISTRATIONS OF COMMERCIAL VEHICLES

(Buses and Goods Lorries)

On 31st March	*Petrol.*	*Diesel*
1948	66,351	363
1949	99,067	1,134
1950	101,508	2,406
1951	116,940	2,840
1952	114,187	3,599
1953	124,439	5,085
1954	124,897	7,510
1955	133,764	13,538
1956	141,116	20,023

SOURCE: Indian Roads and Transport Development Association; Burmah-Shell Oil Storage & Distributing Co. of India (Economics Department).

77 Air traffic has grown at a rate of about 15 per cent annually since 1951 but it is believed that it might drop off to about 12 per cent in future. [*The Financial Times*, Aviation Supplement, 1 September 1958]

78 *Second Five Year Plan*, p. 73.

79

Net Value of Output in Mining, 1950

(Rs. Million)

Value of output	
building materials	41
coal	467
coppe rore and corundum	12
gold	59
iron ore	15
manganese ore	85
mica	66
salt	45
others	43
Total	833
Deductions	111
Net value of output	722

Source: National Income Committee, *Final Report*, February 1954, p. 62.

80 *Second Five Year Plan*, p. 73.

81 See Note 29.

82 The greater relative use of electricity in a developing economy (Latin America, for instance) is clearly illustrated by the increase in the coefficient of electrification which has almost doubled since 1937: See Table on p. 153.

Year	*Total electricity (million kWh)*	*Per capita (kWh)*	*Coefficient of electrification (kWh/kg of petroleum equivalent)*
1929	7,232	72	..
1937	11,205	96	0.275
1948	23,204	157	0.429
1954	37,221	218	0.524

SOURCE: *Energy in Latin America*, pp. 30-1.

83 The 'technical coefficient' method—the method by which constant input coefficients are applied to estimated physical outputs to obtain aggregate input demands—almost always results in over-estimation of total input. Even a relatively small rise in efficiency utilization of one per cent annually leads to a saving of over 20 per cent in fifteen years, although over a short period of time, the cumulative savings in consumption may not be so large. This is probably one of the reasons why most of the energy estimates both in this country as well as abroad, have proved to be generally on the high side. From a situation of energy scarcity in the early nineteen fifties Europe today has progressed to a point when it is positively embarrassed by a glut of energy supplies. [*Electrical Review*, 15 May 1959]

84 & 85 *Report of the Eleventh Census of Manufactures*, Directorate of Industrial Statistics, Ministry of Commerce and Industry, 1956.

86 The price of steam coal per ton increased from Rs. 16.25 in 1949 to Rs. 20.94 in 1957, a rise of 30 per cent, as against a rise of 12 per cent in the wholesale price index during this period. If a base other than 1949 is taken, a different relative rate of increase will be obtained, but there is no doubt that coal prices have been moving faster than other energy sources during the last few years.

87 An increase of 50 nP. in the price of coal was announced recently (*The Statesman*, 25 August 1959) on the recommendation of the Coal Prices Revision Committee which went into the question of costs in the coal industry at the behest of Government of India.

88 Estimated coal-oil parities in industry and other uses were included in an appendix to the Ridley Report on *National Policy for the Use of Fuel and Power Resources,* 1952:

Central heating	2.0
Bakeries	2.5
Open-hearth steel furnaces	2.1
Non-ferrous metal furnaces	3.0
Steam raising generally	1.8
Main line diesel locomotives	5.0
Diesel shunting locomotives	12.0

89 & 90 *The Financial Times,* World Oil, 1958.

91 Metre W. B. and Nagappa Y.,' Oil Prospects in India', *India Quarterly,* April-June 1958.

92 *Progress and Economic Problems in Farm Mechanization,* FAO, 1952.

93 *The Agricultural Situation in India,* July 1956, p. 292.

94 'It is now known for certain that only a very small proportion of this residual area (the 123 million acres of 'other uncultivated lands excluding current fallows') can be brought under the plough at costs which the expected revenue from their cultviation would justify.... The maximum rate of reclamation of new land which might possibly be maintained for a few years would be about 1.5 million acres.' [Reclamation and Settlement of New Lands in India,' *Agricultural Situation in India,* Sep. 1954, p. 348.]

95 *Second Five Year Plan,* p. 269.

96 *Ibid.,* p. 324.

97 *Livestock Census,* Ministry of Food and Agriculture, 1956.

98 *Farm Mechanization,* FAO (Rome), 1956.

99 *Abstract of Agricultural Statistics,* Ministry of Food and Agriculture, 1958.

100 *Farm Mechanization,* FAO (Rome), 1956.

101 Sir B. P. Singh Roy et al. *Suggestions for Agricultural Self-sufficiency,* 1958, p. 18.

102

Analysis of Diesel Power Stations in terms of Plant Capacity
1956

Plant capacity (kW)	*Number of generating stations*
Up to 100	124
101-250	126
251-500	110
501-750	54
751-1000	25
1001-2500	52
2500-5000	9
Total	500

Source: Central Water and Power Commission.

103 For a comparison of unit costs of power from steam, hydro and diesel (internal combustion) engines, see Tables VI-4 and VI-6, *Regional Economic Development and Nuclear Power in India*, National Planning Association, Washington, September 1957.

104 *Energy in Assam* (mimeographed), National Council of Applied Economic Research, 1959.

105 Metre W. B. and Nagappa Y., 'Oil Prospects in India', *India Quarterly*, April-June 1958.

106 *Oil Venture*, Ministry of Information and Broadcasting, Government of India (Undated).

107 Burmah-Shell Refineries Limited, *Chairman's Statement*, 10 August 1959.

108 Metre W. B., 'Future of the Petroleum Industry in India', *Presidential Address*, Geological, Mining and Metallurgical Society of India, 1957.

109 *Oil Venture; Annual Reports* (mimeographed), Oil and Natural Gas Commission, 1956-58.

110 *Neyveli Lignite Project*, Neyveli Lignite Corporation, 1957; *Utilization of South Arcot Lignites*, Central Fuel Research Institute, Dhanbad, 1955.

111 *The Times of India*, New Delhi, 5 August 1959.

112 Two refineries in the public sector, with an aggregate capacity of 2.5 million tons of crude throughput per year, are to be located at Gauhati (As-

sam) and Barauni (Bihar) during the Third Plan. (*Annual Report*, Ministry of Steel, Mines and Fuel, 1959)

113 LAHIRI A. and GHOSAL A., 'Requirements and Resources for Power Generation in India', *Indian Journal of Power and River Valley Development* December 1958, p. 46.

114 *The Times of India*, Bombay, 15 March 1959.

115 HAYATH M. and VIJ K. L., 'Assessment of India's Hydro-Electric Resources', *Power Engineer*, Vol. 7, 4, 1957, pp. 200-4; VIJ K. L. and CHANDRAN C. K., 'Regional Planning for Power', *Ibid.*, pp. 218-24.

116

COAL COSTS AT SELECTED CENTRES IN INDIA

Area	*Source & quality of coal*	*Approximate average price* *At Pithead* Rs.|ton	*Delivered* Rs.|ton
Rajasthan	Medium grade coal from Central Indian collieries in M.P.	17-19	37-45
Ahmedabad	—do—	17-19	37-42
Bombay	—do—	17-19	40-45
Cochin	Medium grade coal from Singareni, Andhra	17-19	43-50
Madras	—do—	17-19	39-45
	From Bengal and Bihar via sea from Calcutta	17-19	60-70

SOURCE: Railway Board; State Electricity Boards; Tata Industries Ltd., Bombay.

117 Ministry of Railways (unpublished information).

118 KULKARNI H. R., '*Economics of Power Transmission*', All-India Power Engineers' Conference, 1957.

119 & 120 VIJ K. L. and CHANDRAN C. K., *Power Engineer*, Vol. 7, 4, 1957, p. 223.

121 HAYATH M. and VIJ K. L., 'Economic Trends in the Production of Hydro Energy in India', *World Power Conference*, Sectional Canadian Meeting, Montreal, 1958.

122 VIJ K. L. and CHANDRAN C. K., *Power Engineer*, Vol 7, 4, 1957, p. 222.

123 *Energy in India* (mimeographed), National Council of Applied Economic Research, 1959.

124 Reference may be made to the following: (1) *Peaceful Uses of Atomic Energy*, United Nations, Vol. I, 1956 and 1958; (2) *Economic Applications of Atomic Energy*, United Nations, 1957; (3) *Regional Economic Development and Nuclear Power in India*, National Planning Association, Washington, 1957; (4) *Some Aspects of the European Energy Problem*, OEEC, 1955; *The Cost of Atomic Power*, Shell-Mex, Great Britain, 1958; BHABHA H. J. and PRASAD N. B., *A Study of the Contribution of Atomic Energy to a Power Programme in India*, 1958; BHABHA H. J., 'On the Economics of Atomic Power Development in India', *The Advancement of Science*, Vol. XIV, 1957, pp. 159-74; DUBASHI J. D. 'Prospects of Nuclear Power in India', *The Indian and Eastern Engineer*, September and November 1956.

125 BHABHA H. J. and PRASAD N. B., *A Study of the Contribution of Atomic Energy to a Power Programme in India* (mimeographed), 1958, pp. 30-4.

126 BHABHA H. J., Address to the Institute of Science, Bangalore, February 1959.

127 YADAVA MOHAN and SWAYAMBU S., *Power Engineer*, Vol. 6, 2, 1956, p. 88.

128 Rates of growth for some selected countries are given below (in percentage) for 1950-55:

Country	*Rate of increase in national income*	*Rate of increase in energy consumption*
Brazil	3.2	12.9
Canada	6.7	5.7
West Germany	8.1	6.6
France	6.4	4.3
Italy	7.3	11.2
Japan	7.6	6.6
Switzerland	3.8	7.3
United Kingdom	3.2	2.2
United States	4.7	3.2

SOURCE: United Nations; United Kingdom Atomic Energy Authority; OEEC; Atomic Energy Bureau, Japan.

129 Institute of the Study of the USSR, *Bulletin*, Vol. V, 7, 1958, pp. 17-25.

130 *Steel Review*, 6, 1957,

INDEX

Agriculture
- implements in India, 94
- population employed in various countries, 7

Atomic Energy Commission, 102

Balance-sheet
- for electricity demand, 47
- for non-electrical energy demand, 48
- for total energy demand, 15-6, 18

BTU input per dollar of GNP, 4

Census of Manufactures, on prices of coal and fuel oil, 87

China's First Five Year Plan, 23

Coal consumption
- industry, 89
- railways, 62-3, 123
- estimate of gross demand, 112

Coal resources in India, 105

Coefficients
- for electricity, conversion, 46
- of electrification in industry, 83, 85, 86
- of petroleum in industry, 86
- correlation, 38

Committee on Requirements and Utilization of Fuel, 22

Consumption
- Coal
  - industry, 89
  - railways, 62-3, 123
- Diesel oil
  - diesel stations, 104
  - oil engines, 96
  - road traffic, 76, 78
  - tractors, 95
- Electricity
  - demand, 121-2
  - effective, 101
  - estimate of gross, 105
  - households, 41-3
  - industry, 41, 85
  - irrigation, 44
  - railways, 123
  - services, 43
- Energy
  - agriculture, 124
  - by sectors, estimate of, 98
  - by type, estimate of, 99
  - function, 8, 111
  - households, 50, 122-3
  - industry, 6, 80, 82, 124
  - primary, 19, 31, 126
  - railways, 67
  - total effective, 19, 23, 31, 121
  - transportation, 123
- Kerosene
  - households, 51
  - heat, 52
  - heat and lighting, 58
  - lighting, 52-4
- Petroleum
  - aviation and shipping, 79
  - industry, 87-9
  - road traffic, 76, 78

Correlation coefficient, 38

Cost
- capital
  - electric plants, 106-7
  - hydro schemes, 107
  - nuclear power, 108
  - oil exploration, 103
  - thermal stations, 107
- real, of thermal stations, 107
- unit, of power from hydro stations, 107

Diesel oil consumptiion in road traffic, 76, 78

Diesel stations
  estimated output of electricity from, 102
  oil consumption by, 104
Draft power in the world, animal and mechanical, 93

Elasticity for energy consumed as a factor in production, 9
Electricity consumption
  and net national output, 34, 36
  by sectors, 46
  demand, 121-2
  effective, 101
  estimate of gross, 113
  in households, 41-3
  industry, 41, 85
  irrigation, 44
  services, 43
  railway traction, 44-5
  in railways, 123
  per capita and incomes per capita, relationship between, 34-6
Energy Consumption
  and Gross National Product. 3-6, 26
  and income elasticity, 5, 19
  and net national output, 20
  and national economy, 110
  by sectors, estimate of, 98
  by type of energy, estimate of, 99
  demand for domestic primary, 54-5
  expenditure elasticity of net, 27
  function, 8, 111
  income elasticities of domestic, 8
  income elasticity of primary, 9
  pattern of gross demand by source, 106, 107
  per capita and incomes per capita, relationship between, 1-3
  per capita gross, 28
  primary, 19, 31, 126
  in agriculture, 124
  in households, 50, 122-3
  in industry, 6, 80, 82, 124
  in railways, 67
  in transportation, 123
  total effective, 19, 23, 31, 121
Energy, pattern of generation by source, 126
Expenditure elasticity of net energy consumption, 27

Five Year Plan
  China's First, 23
  Fifth, targets of per capita income and national income, 13
  Second, per capita incomes, 13
Fuel efficiencies on railways, 67

Gosplan of Russia, 103
Gross National Product
  and energy consumption, 3-6, 26
Gross energy consumption, 28, 107

Hydro-potential of India, 106-7

Income elasticity
  and energy consumption, 5, 19
  of domestic energy consumption, 8
  of primary energy consumption, 9
Index of industrial elasticity, 40

Kerosene consumption in households, 51
  heat, 52
  heat and lighting, 58
  lightnig, 52-5

Livestock census of 1956, 92

Natural Resources Division, 21, 37
Net national output
  and energy consumption, 20
  and electricity demand, 34, 36
Non-electrical energy, demand for, 86
Nuclear energy,
  economics of, 108-9
  estimated output of, 109

Occupational pattern in India, 7-8

Oil consumption
  by diesel stations, 104
  by oil engines, 96
  by tractors, 95
Oil engines, oil consumption by, 96

Pattern
  occupational, of India, 7-8
  of generation by source of energy, 126
  of gross demand by source of energy, 106-7
Pattern of consumption
  total energy
    by type of energy, 99-100
    industry, 81-2
    primary, 113, 115
    secondary, 111
  coal in railways, 62-3
  diesel oil, 76, 78
  electricity, by sectors, 46
  fuel in railways, future, 68
  kerosene, 52
  petrol, 76, 78
Per capita incomes
  and per capita energy consumption, 1-3
  and per capita electricity consumption, 34-6
Petroleum coefficients in industry, 86, 88, 89
Petroleum consumption
  in aviation and shipping, 79
  estimate of gross demand, 112
  in industry, 87-9
  in road traffic, 76, 78
Population employed in agriculture in various countries, 7
Price rate
  coal and fuel oil, 87, 107
  diesel oil per ton, 102
  electricity per kWh, 102
Primary energy consumption, 19, 126
  effective, 31
  income elasticity of, 9
Production
  coal, in China, 23
  coal, in India, 105
  electricity, 101, 105
  hydro-electricity, 106
  industrial, and electricity consumption, 28
  nuclear power, 109
  petroleum, 103
Projection of energy demand, factors, 11-2

Resources of coal in India, 105
Road Development Plan, 72, 78

Saving in fuel through substitution, 17

Tractors, number of, in selected countries, 93, 95, 124
Transportation energy, coal requirements, 123

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